GROUND-WATER RESOURCES

Introduction

Most of Klickitat County's household and irrigation water supplies are derived from ground-water sources, which include both springs and wells. In areas of high effective precipitation, springs are abundant and provide some household and stockwater supplies. However, in much of the county wells are the primary water source.

Ground water constitutes that part of an area's annual precipitation that is not lost as runoff or evapotranspiration and which percolates into the subsurface. A ground-water system is dynamic so that recharge to and discharge from the subsurface is an ongoing process. The storage capability of the subsurface is not infinite and maintenance of adequate ground-water supplies depends upon annual recharge in quantities sufficient to keep pace with ground-water use. In order to determine if adequate ground-water supplies exist, it is necessary to evaluate a wide variety of related information.

Ground-water information is presented in several sections of this report. However, most of the raw data collected are presented in the Appendix. In the following sections, type of data collected is discussed, followed by a discussion of the general water-producing capabilities of the major geological units in the county. Finally, an analysis of the availability of ground water for individual areas in the county is presented.

Basic Data

Several methods of data collection were used in obtaining information on ground-water supplies. A county-wide well inventory was prepared, drilling information from recorded driller's logs was compiled, monitoring wells were established throughout the county, and borehole geophysical data obtained from selected wells were evaluated. Mass water-level measurements of wells in the Goldendale-Centerville area which were made by Washington State Department of Ecology personnel in 1974 and 1975 have been included. A brief description of each of these investigative methods is provided below.

Well Inventory

Wells far exceed all other sources for water supplies in Klickitat County, and a majority of these were inventoried. The inventory included the collection and evaluation of existing records and the canvassing of most of the county to obtain information from individual well owners. In the canvassing effort, static water-level measurements were made whenever possible. The results of the inventory are presented in Appendix B.

List of Selected Well Logs

Appendix C contains driller's logs for selected wells throughout the county. The logs are presented to provide general information on drilling conditions in specific areas of the county and to provide more detailed information on some of the wells included in the well inventory. In most cases, the selected wells can be considered representative of the subsurface and aquifer conditions in the county.

Observation Wells

Monthly water-level measurements were made in 24 observation wells at various locations throughout the county. Wells in this network were selected to provide information characteristic of the several areas of differing subsurface hydrology. The measurements provide baseline data on the annual and long-term fluctuations in water level of these areas. The data collected from the observation wells is tabulated in Appendix D and graphically presented in well hydrographs. Water-level measurements made by the U. S. Geological Survey in three additional wells are included.

Borehole Geophysics

Borehole geophysical logs were run in selected wells in the Bickleton and Goldendale-Centerville areas to obtain additional stratigraphic and hydrologic information. Geophysical logging of a well involves trolling the well with special sondes, or tools, which respond to changes in various borehole parameters. Borehole geophysics is useful in obtaining information on geologic conditions, as well as in locating aquifers and analyzing water movement in a well.

The wells for which geophysical logs were prepared are noted in Appendix B and, although the log responses, per se, are not reproduced in this report, the information obtained from the borehole geophysics is incorporated in discussions of the hydrology of the respective areas.

Mass Water-Level Measurements

A need for discrete hydrologic information plus concern over the possible effects of increased ground-water withdrawal in the Goldendale-Centerville area prompted the Department of Ecology to initiate a study of that area. The study included the measurement of static water levels in all available wells within the study area during the spring and fall for a two-year period. The object of the mass measurement was to define the water table and/or potentiometric surface of the area and to ascertain the effect of heavy ground-water withdrawal on these surfaces. To eliminate the direct effects of pumping, the measurements were made in the early spring, before most irrigation began, and late in the fall after irrigation had ceased.

Static water-level measurements were made in the spring and fall of 1974 and 1975 by department personnel and are incorporated in this report. Appendix E presents the raw field measurements along with well-head elevations estimated from U. S. Geological Survey topographic maps. From this tabular information, water level elevations were calculated and contoured for each measurement period.

Well Numbering System

To avoid confusion in well locations a system used by the U. S. Geological Survey was adopted in this report. Each well is given an alphanumeric designation based upon the legal description of the land on which it is located.

The well is located first by township and range and then by section. Because all of Klickitat County is north of the Willamette Base Line and east of the Willamette Meridian, the directional notation normally accompanying legal descriptions is omitted. Each section is then divided into sixteen 40-acre parts, each with a different letter designation as shown in Figure 59. The identification number of each well, then, consists of the township and range, followed by the section, which is in turn followed by the letter designation of the appropriate 40-acre plot. Thus, a well located in the 40-acre area corresponding to the NW 1/4 of the NW 1/4 of Section 24, T. 3 N., R. 15 E. would be 3/15-24D1. If more than one well is located on the same 40-acre plot, they are coded in numerical order according to their relative ages. Thus, if two wells were located in the above described 40-acre area,

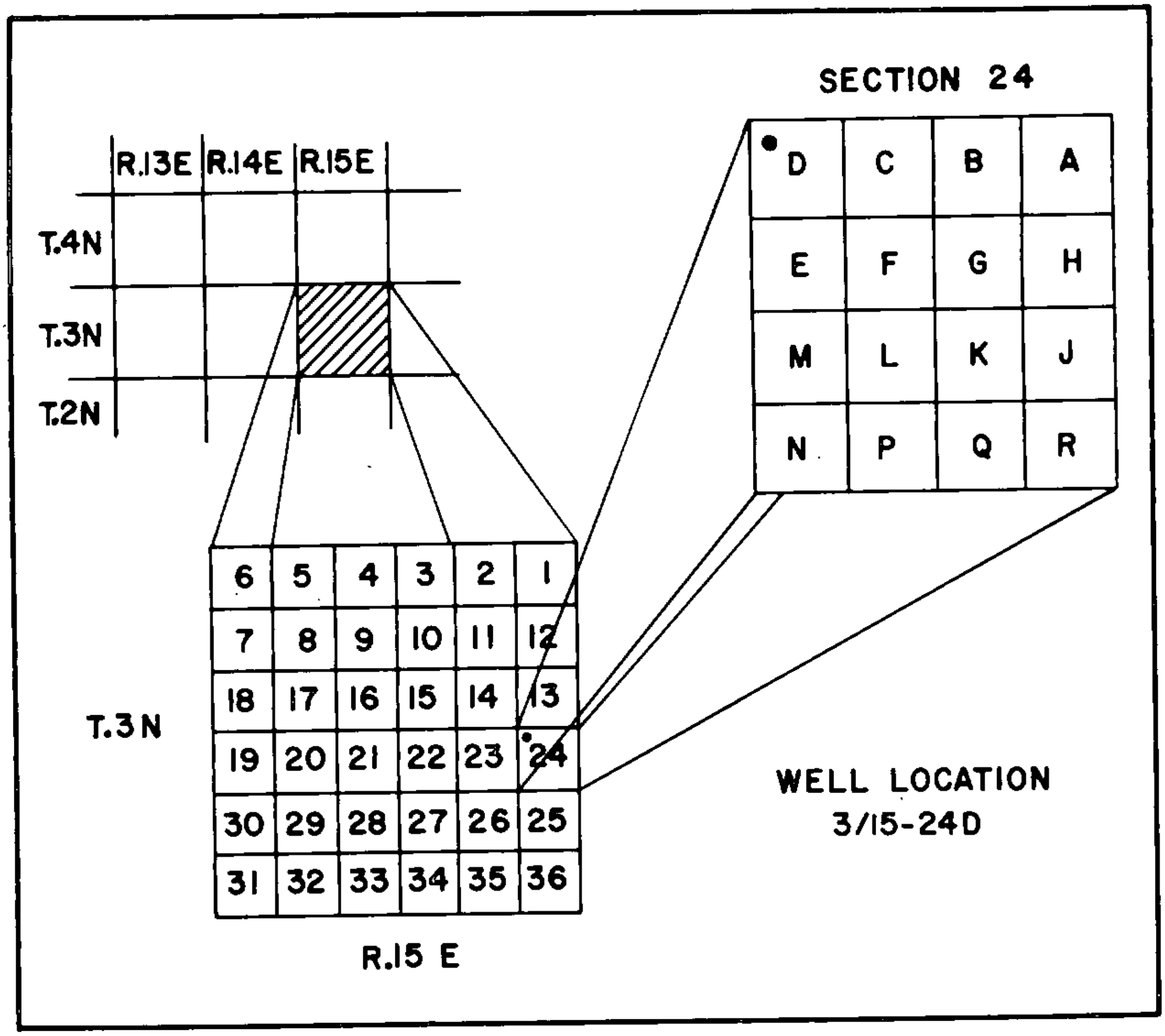

FIGURE 59. Explanation of well location and identification system.

the older would be 3/15-24D1 and the younger would be 3/15-24D2. Springs illustrated on Plates I and II use the same system; however, the number is followed by a lower-case "s" to avoid possible confusion with a nearby well.

Ground-Water Occurrence

In the discussion of reconnaissance geology of the county, four major mappable units were delineated. The map on Plates IV and V shows the surface distribution of these four units and also illustrates the major geologic structures. These principal geological units within the county are also the principal sources of ground water. Some basic premises concerning the availability of ground water in these four units can be established.

Older Volcanics

As previously mentioned, outcrop of the older volcanics is limited to the extreme western part of the county. Much of this part is U. S. Forest Service land and there have been few attempts to locate sources of ground water. In spite of the lack of direct evidence concerning the availability of ground water in the older volcanics, some indirect evidence provides an indication of the unit's water-producing capabilities.

Examination of the older volcanics in hand specimen and in outcrop indicates very compact, dense tuffs and tuff breccias. In addition, reconnaissance of the outcrop areas indicates that few springs issue from the older volcanics and volcaniclastics. The compact nature of the volcanics and the lack of springs in the outcrop areas would suggest that, because of low porosity and permeability, the older volcanics and volcaniclastics are not good ground-water sources. In some areas, however, jointing and fracturing may have produced sufficient secondary porosity and permeability to permit domestic water production. It is possible that some ground water might be available from the coarse sediments that can occur between volcanics and the dense volcaniclastics. The availability of water from these zones would depend upon their lateral variation and their extent.

Columbia River Basalt

Basalts of the Columbia River Group have proved to be substantial ground-water source rocks over much of the Columbia Plateau and are the principal source of ground water for most of Klickitat County. The occurrence of ground water within the basalts is unique in comparison to other water-bearing geological units.

The Columbia River Basalt Group consists of a thick series of basalt flows in which individual flows average 100 feet in thickness and are often separated from each other by tuffaceous interbeds of varying thicknesses. Examination of an individual basalt flow in otucrop reveals most of the flow's central part to be very dense and compact with associated low porosity and low horizontal permeability. This dense central part of the flow, although it may be saturated, is in most cases not a productive zone because of its extremely low permeability.

Near the top of most basalt flows, however, is a much less dense, vesiculated zone with a characteristic honeycomb appearance (Figure 60). This

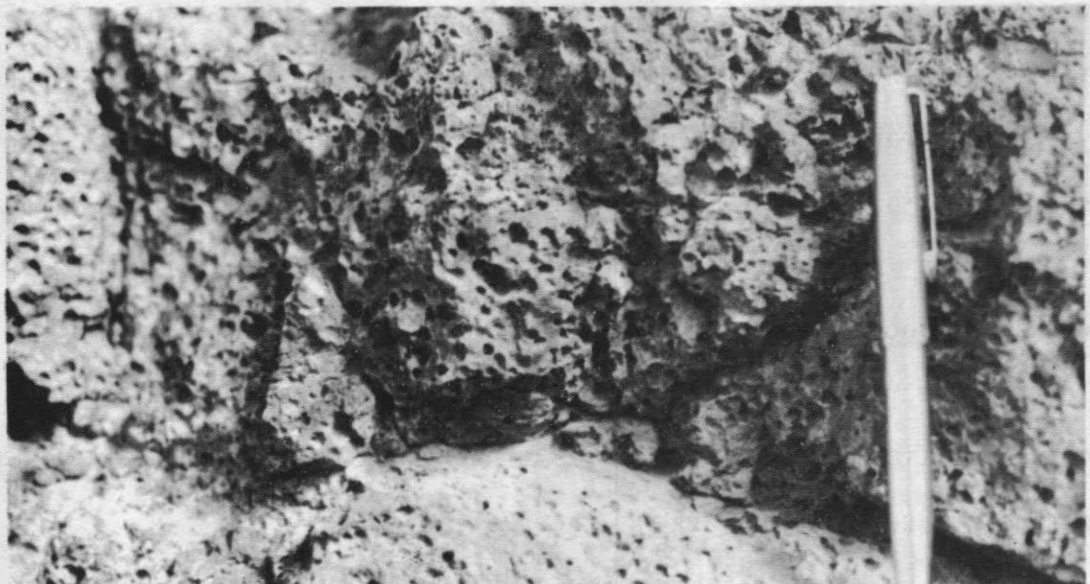

FIGURE 60. Highly porous, vesicular basalt flow top.

zone was formed during the cooling of the molten lava as gases rose to the surface of the flow. As the flow cooled, some of this gas became trapped as bubbles near the flow surface and formed a network of bubble holes. Unlike the bulk of the basalt flow, this vesicular part has high porosity and very high horizontal permeability, which makes these vesicular flow tops and interflow zones excellent aquifers. Sediments interbedded between flows may also produce adequate ground-water supplies if their porosity, permeability and lateral extent are satisfactory.

Although most basalt flows of the Columbia River Group within the county have a relatively large areal extent, the same interflow zone in any two locations may not necessarily produce water. Similarly, the same interflow zone may be an aquifer at different places but the production obtained in two wells penetrating the zone may be markedly different. The principal reason for this inconsistency is lateral variation of permeability of the interflow zone. In some cases the porous interflow zone may thin appreciably over a short distance. Permeability of these porous zones within the basalts also may be affected by secondary filling of pore spaces with clay or other minerals. Thus, whereas sufficient porosity may be present, permeability might be so restricted as to make sustained production nearly impossible.

In addition to lateral variation within the permeable zones, their continuity and distribution may be affected by structure and erosion. Geologic structures such as folds and faults disrupt the continuity of the permeable zones and often act as zones for vertical migration of ground water. If such structures are present between a well and the principal area of recharge, the well may have poor production. Similarly, deep erosional canyons which penetrate several basalt flows can dissect the permeable zone and limit lateral continuity. An example of this lack of continuity can be seen in the Rock Creek basin, where dissection of the basalt surface prevents recharge from distant areas and restricts recharge in the undissected areas to that available from direct precipitation. Thus, in areas of relatively low effective precipitation, the lack of aquifer continuity results in a generally inadequate ground-water supply. Conversely, excellent aquifers may exist in areas of Klickitat County where basalt flows and their related porous interflow zones have sufficient continuity. In the Goldendale area, many shallow irrigation wells (less than 1000 ft) yield 500-800 gpm whereas others yield as much as 1500 to 2000 gpm. In the eastern end of the county, deeper irrigation wells yield 2000 to 3000 gpm.

Tertiary-Quaternary Sediments

The Tertiary-Quaternary sediments are also capable of good ground-water production and, like the underlying basalts, the potential for adequate ground-water production from the sediments is generally tied to their continuity and permeability. Geologic evidence indicates that in many areas the sediments were subjected to erosion prior to their capping by the younger volcanics. Because of this erosion, distribution of the sediments is highly variable and results in continuity problems similar to those of the highly dissected basalt areas.

Permeability in sediments is normally a function of the overall nature of the sediments, including particle size and sorting. In the Goldendale area, these sediments are dominantly coarse sands, gravels and conglomerates, are quite permeable, and occasionally will produce 100-200 gpm. In areas to the south and west, the sediments are finer-grained clays and tuffs and yield only a few gallons per minute in most cases. In general, the best production from the younger sediments is obtained in the area north and west of Goldendale where the permeable sediments underlie the younger volcanics. Substantial production from these sediments has also been obtained in the Swale Creek valley.

Tertiary-Quaternary Volcanics

In some areas of the county, the younger volcanics yield sufficient ground water for domestic and minor irrigation uses. Like the basalts of the Columbia River Group, the olivine basalt and andesite flows of the younger volcanics have porous flow tops and interflow zones which can be productive aquifers. The younger volcanics differ from the Columbia River basalts in that individual flows are much more limited in extent. Furthermore, many of the flows are restricted to linear channels or are otherwise unevenly distributed, thus limiting the distribution and continuity of potential aquifers. The coarse, open diktytaxitic texture of many of the younger basalt flows permits good vertical and lateral migration of water within the flow and may allow for more rapid recharge than possible in Columbia River basalt. For the most part, where there is sufficient continuity and recharge, the younger volcanics are capable of sustaining good domestic water production. In many of the nothern and western parts of the county, the high effective precipitation and the generally porous nature of these flows make them an important domestic source.

Unconsolidated Sediments

In the Camas Prairie area, unconsolidated sediments approach 200 feet in thickness. The sediments extend over a 50-square-mile area and consist of gravels, sands, silts, and clays. As in the case of the other sediments discussed, ground-water production is related to sediment type and distribution.

In the Camas Prairie area wells tapping coarse, highly permeable beds within these sediments are capable of substantial production.

Availability of Ground Water Within the County

Dead Canyon Area

The Dead Canyon area in the eastern end of Klickitat County has recently been found to produce large quantities of ground water for irrigation. The area encompasses Townships 5 and 6 north and Ranges 22 and 23 east. Geology of the Dead Canyon area is characterized by glacial slackwater silts overlying basalts of the Columbia River Group. The uppermost basalt flow is the Elephant Mountain Member, which is thought to underlie almost all of the area. The area is lacking in complicated structure and is typified by a broad gentle slope dipping south from the Horse Heaven anticline to the axis of the Swale Creek syncline. Dead Canyon, Juniper Canyon and several lesser drainages dissect the area but generally do not exceed 200 feet in depth. Much of the area is undissected.

While a few intermittent springs occur in some of the canyons, wells are the only reliable source of ground water in the area. Until recently, the very low population density in the Dead Canyon area meant that relatively few wells were drilled. The existing wells were drilled mainly for domestic and stockwater uses and average 150-200 feet in depth. Production in these wells was normally obtained from the top of the Pomona Member. This suggests that the units above the Pomona Member (the Rattlesnake Ridge Interbed and Elephant Mountian Member) are not likely sources for ground-water production in this area. In some parts of the area, domestic wells have been drilled to the

Selah or Mabton interbeds, at depths of 500 to 600 feet, to acquire adequate domestic water.

In recent years, deep-well irrigation has proved successful, and several large-diameter, high-volume wells are now in production. This indicates that aquifers capable of substantial production are present at depths of 700 to 1000 feet. Analysis of drilling and geophysical well logs from several of these deep wells indicate that production is obtained from interflow zones between flows of the Priest Rapids Member and from similar zones between Frenchman Springs and Priest Rapids Members.

One of the earliest irrigation wells drilled in the area (6/23-15H1) obtained a free flow of 2200 gpm from the interflow zone within the Priest Rapids Member. Comparison of water level information and borehole geophysics for this and a well 10 miles to the southwest (5/22-27A1) led Crosby and others (1972) to suggest that the aquifer was continuous over much of the area. Recent drilling of additional wells indicates that this may be correct.

Water-level measurements in Well 5/23-3A2 (Figure 61) indicate little annual fluctuation. The sudden rise in water level apparent in the summer months of 1976 is not readily explainable but may be caused by recharge of the shallow aquifers associated with the drilling of increasing numbers of deep wells with high positive heads.

The recent increased use of ground water in the Dead Canyon area and the lack of historical records make it difficult to assess the effect of ground-water withdrawal. Conversations with well owners, however, indicate that some decline in head is becoming evident in the area. The limited amount of recharge available suggests that further decline in hydrostatic head might be anticipated as ground-water withdrawals are continued and increased.

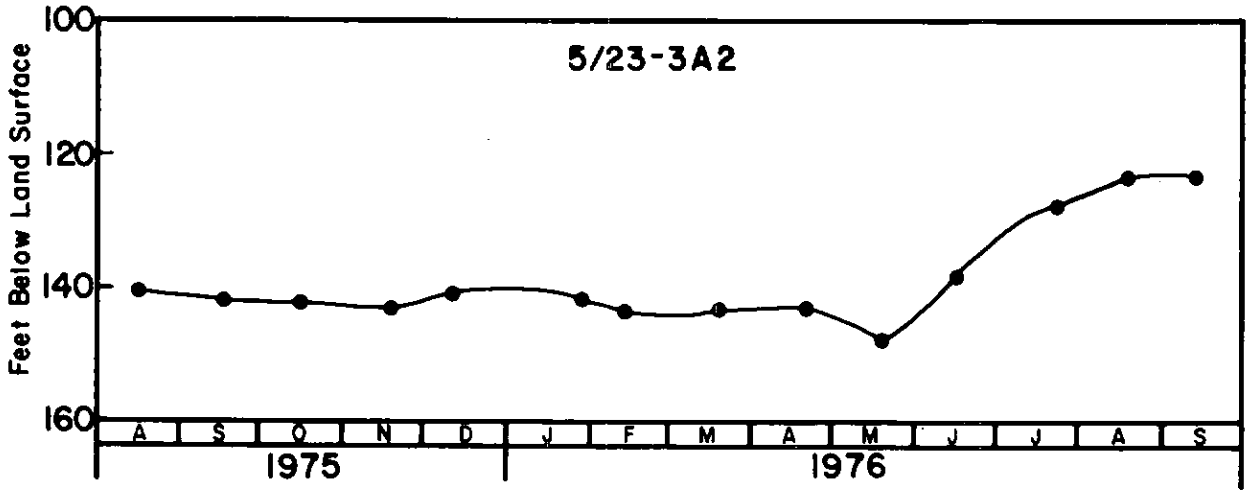

FIGURE 61. Water-level hydrograph, observation well 5/23-3A2, Klickitat County, Washington.

Six Prong Area

The Six Prong area includes much of the Alder Creek drainage basin and the lower part of the Pine Creek and Wood Gulch Basins. The area is dissected by numerous tributary drainages, which results in a series of narrow plateaus separated from each other by deep canyons. The plateaus are normally used for dryland wheat production and the canyons for grazing. The area has a low population density and there is relatively little demand on the ground-water resource. Most ground water is used for domestic and stock needs and is obtained from shallow wells or, to a lesser extent, from springs in canyon areas. Like the Dead Canyon area, many domestic wells tap interflow zones associated with the Selah or Mabton interbeds. In some locations, the intense dissection of the area creates water supply problems, and attempts to develop wells are often unsuccessful because of the limited lateral continuity of the shallow aquifers. Water can usually be obtained, however, if the wells are drilled to levels below the bottom of the canyon. Depending upon the location of these wells, static levels can often be quite low.

In general, there is minimal irrigation activity in the Six Prong area, principally because the area's rugged topography limits irrigation feasibility. In the lower part of Alder Canyon, however, recent attempts to obtain large amounts of water from deep wells has proved quite successful, and substantial crop irrigation is now being attempted. Most of the irrigation wells have been drilled to the top of the Priest Rapids Member or below (800-1000 ft) and obtain substantial quantities of water from interflow zones within the Priest Rapids or Frenchman Springs members. Most have high static water levels and one (5/23/29D1) is free-flowing in excess of 2000 gpm.

Bickleton Area

The Bickleton area includes the upper end of the Alder Creek basin and the central and northern parts of Pine Creek and Wood Gulch basins. In this area, stream dissection is much less severe than in the Six Prong area, and much of the Bickleton area comprises a level, gentle southward-dipping plateau. This level plateau area lends itself to dryland farming and, accordingly, much of the population in eastern Klickitat County is located in and around the town of Bickleton.

Although the subsurface geology of the Bickleton area appears to be very similar to that of the Dead Canyon area, the hydrology of the two areas is remarkably different. Drilling information and borehole geophysics indicate that the interflow zones associated with the Selah and Mabton interbeds are the principal sources for domestic water in the Bickleton environs. The Selah interflow zone is generally a poor producer and most good domestic wells are drilled to the Mabton (300-400 ft). In isolated cases, the Mabton interbed is compatible with moderate (500 gpm) irrigation production.

Subsurface information indicates that units similar to those found in the Dead Canyon area exist in the Bickleton area and that similar zones of high porosity are present. Attempts to obtain water from interflow zones between Priest Rapids flows or between the Priest Rapids and Frenchman Springs members have resulted in very low hydrostatic heads and productions on the order of a few tens of gallons per minute. Well 5/22-27C1 was completed to a depth of 900 feet, had a static level of 750 feet below land surface, and did not produce sufficient irrigation water.

Measurement of water levels in the Bickleton area has revealed considerable information on the area's hydrology. As previously mentioned, domestic wells in the area vary in depth and tap different stratigraphic intervals. In spite of this, water levels from almost all wells appear to define a single surface which is, in most places, within a few tens of feet of the ground surface. This relationship appears to hold over most of the Bickleton area with one noticeable exception. In the southwest part of T. 6 N., R. 21 E., and the northwest part of T. 5 N., R. 21 E., there is an area where aquifers associated with successively lower stratigraphic intervals between the surface and the top of the Priest Rapids Member exhibit progressively lower hydrostatic heads. The abruptness of the change is apparent in comparing the depths and water levels of wells 6/20-36B1, 6/21-31F2 and 6/21-31F4. These wells are drilled to similar stratigraphic levels except for 6/21-31F2 which terminates about 50 feet higher than the other two. Well 6/20-36B1 is about 0.5 miles west of and 40 feet higher than the other two. Well 6/20-36B1 is about 0.5 miles west of and 40 feet higher in elevation than 6/21-31F2 and 31F4. The static water level in 6/20-36B1 is about 12 feet from land surface, in striking contrast to that of wells 6/21-31F2 and 31F4. Water levels in these latter wells are 197 and 270 feet below land surface, respectively. In addition to the striking difference in water levels, the anomalous area has a history of poor production, even for domestic supplies. This anomaly in hydrology is probably related to a permeability change, but the cause of the change is unknown.

Water-level measurements in the Bickleton area wells also reveal that a substantial head change occurs between wells which terminate above the Priest Rapids Member and those which penetrate the Frenchman Springs Member. Only two wells, 5/22-27C1 and 6/21-19Q1, have been drilled below the Priest Rapids, but both have reported static water levels of 700 feet or greater below land surface. Information obtained from conversations with area residents suggests that a zone of intermediate head may exist in wells which penetrate part of the Priest Rapids Member but which do not penetrate the Frenchman Springs Member.

Monthly water-level measurements in selected wells indicate that annual fluctuation varies among the wells and depends upon their depth and location. Some of the hydrographs also suggest that an overall decline in ground-water levels is occurring. In the immediate area of the community of Bickleton, water-level information is available from two wells. Well 6/20-22D1 has been measured regularly by the U. S. Geological Survey and provides the longest available record for the area. This well is reported to be 44 feet deep, which means that it bottoms somewhere in the Pomona flow. During the last three years, the hydrograph (see Figure 62) appears to indicate an overall decline in water level, with recovery during winter and early spring months not equaling that of previous years. Unfortunately, only two measurements were made in 1974 and 1975 and these may present a distorted picture. The

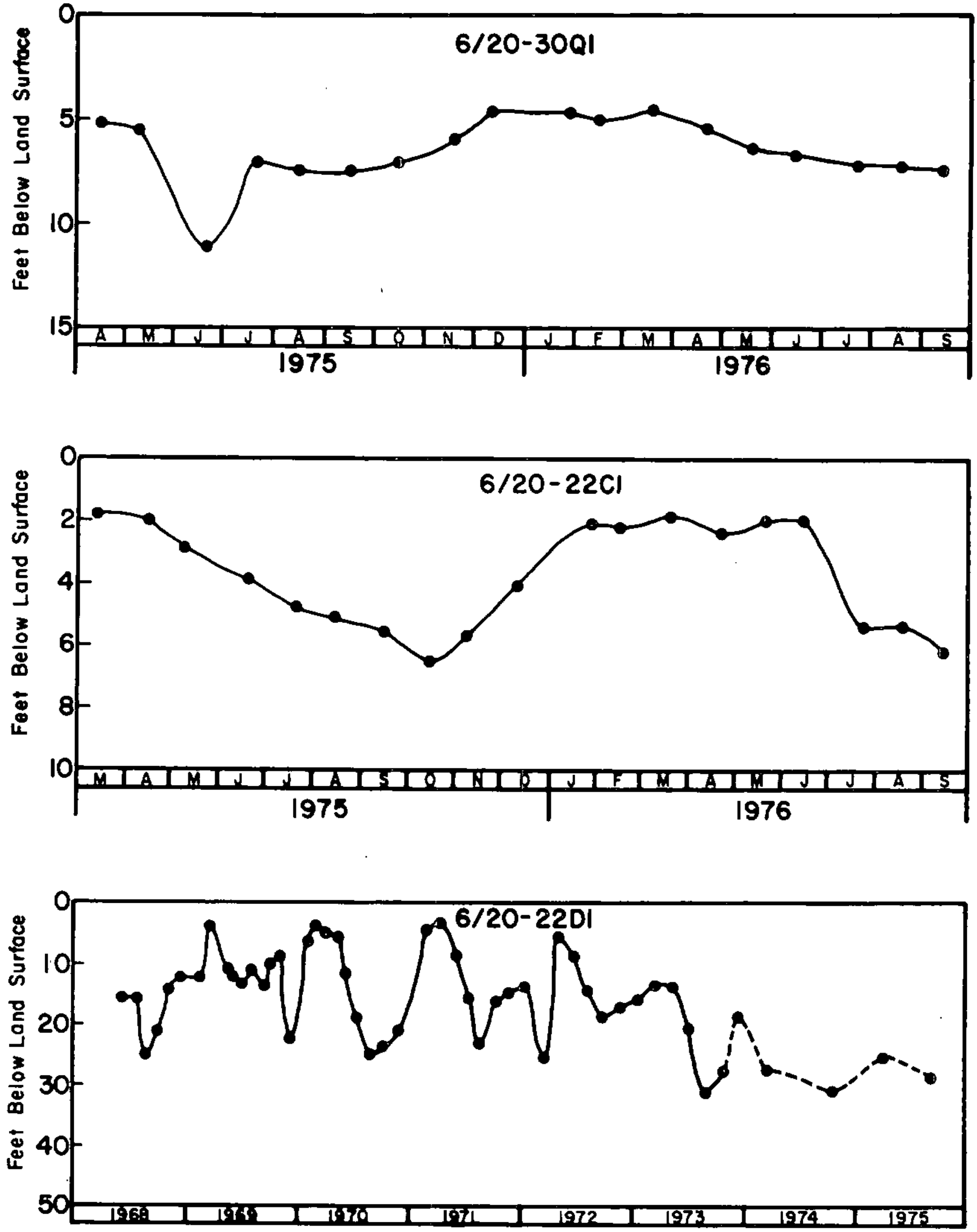

FIGURE 62. Water-level hydrographs, observation wells 6/20-30Q1, 6/20-22C1, and 6/20-22D1, Klickitat County, Washington.

twice-yearly measurements were made, however, in the early spring and in the fall and should approximate the annual maximum and minimum for the well. If the measurements for 1974 and 1975 can be taken as representative, an overall decline of about 20 feet has taken place over the last four years. In contrast, well 6/20-22C1, located only two blocks to the east, indicates little overall decline in 1975 and 1976. This well is about 100 feet deeper than 6/20-22D1, has a relatively high static water level, and displayed good annual recovery for the 18 months during which it was measured. Monthly water levels are also available from the two wells in the earlier mentioned anomalous area. Hydrographs of both wells (Figure 63) show a net decline in water levels over the period of measurement with declines being most pronounced in 6/21-31F4. Similarly, measurements made in 6/21-34N1 (Figure 63) also indicate an overall decline during the period of measurement.

The apparent decline in these Bickleton area hydrographs may be a result of higher than normal precipitation in 1975 followed by much lower than normal precipitation in 1976 rather than a decline caused by ground-water use. This explanation seems unlikely, however, for two reasons. One is that, although annual precipitation for the Bickleton area during 1976 was about one-half of normal, most of the deficit occurred in the fall and early winter months, after the final water-level measurement. Weather Bureau records show the 1976 annual precipitation to be 6.93 inches, in contrast to normal annual precipitation of 13.04 inches. However, the records also show that by the end of September 1976, the last month of water-level measurements, precipitation was only 1.83 inches behind normal. The records indicate that yearly fluctuations from two to three inches are not uncommon, and it seems unlikely that such fluctuations would have such an immediate effect upon the deeper ground-water zones.

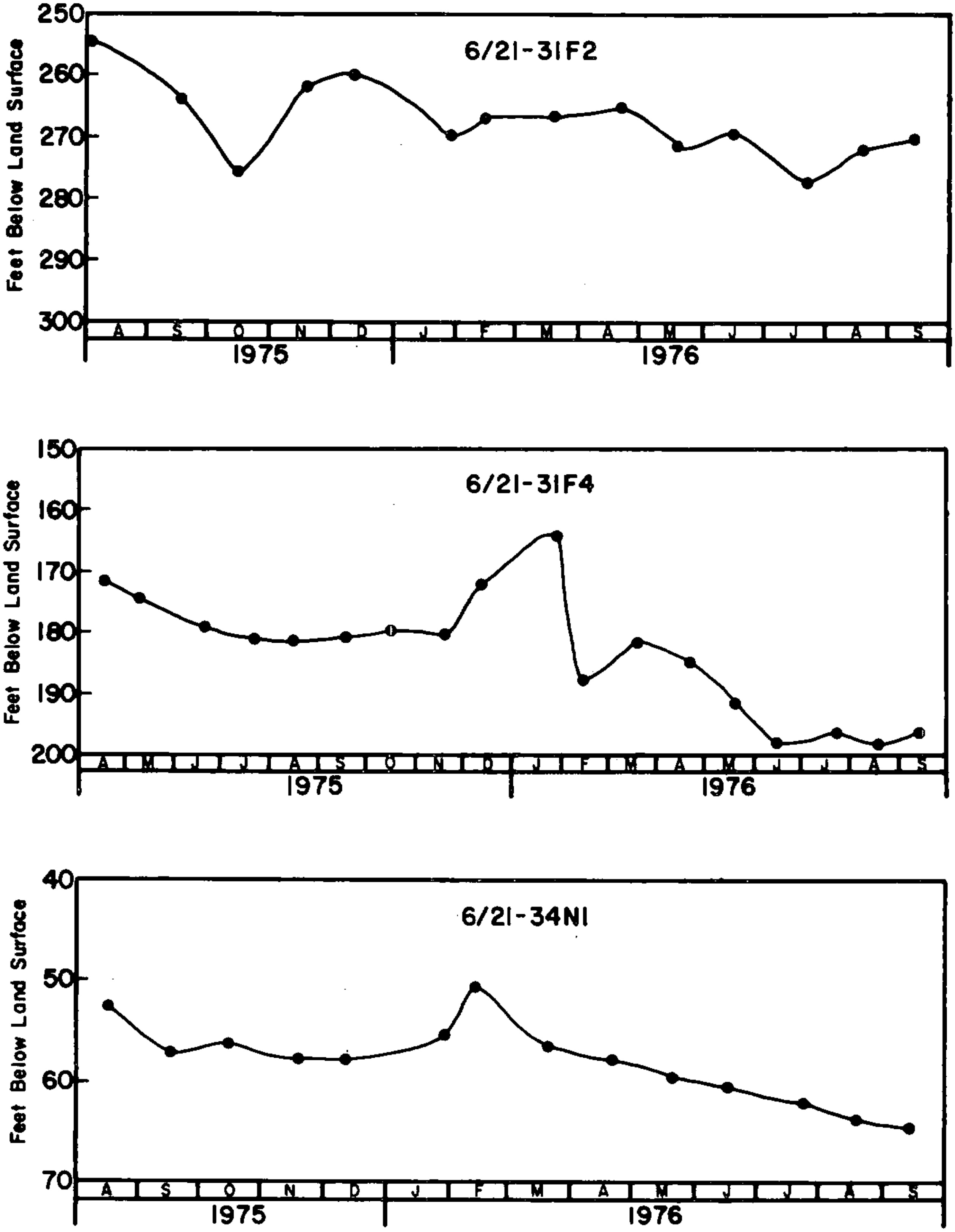

FIGURE 63. Water-level hydrographs, observation wells 6/21-31F1, 6/21-31F4, and 6/21-34N1, Klickitat County, Washington.

The second line of evidence that the water-level decline may not be a direct result of variations in precipitation is that such variation should produce a more profound effect upon the shallower wells. Such an effect is not noticeable. The Cleveland well (6/20-30Q1) is only 14 feet deep and depends on direct annual recharge. Still, it exhibits relatively little annual fluctuation and no overall decline. If annual precipitation varied enough to affect recharge, the effects should be evident in the hydrograph of this well.

Continuation of declining water levels could have far-reaching effects upon the Bickleton area. If the aquifer associated with the Mabton interbed ultimately were to be dewatered, production would most likely have to come from much deeper zones in the Priest Rapids and Frenchman Springs members. To date, efforts to increase ground-water production for the Bickleton area from these lower zones have been discouraging. Drilling information does suggest that adequate domestic water may be available; however, the depressed hydrostatic head associated with these lower aquifers would require much greater pump lifts.

Rock Creek Area

West of the Bickleton and Six Prong areas, the Rock Creek drainage basin occupies a large part of east central Klickitat County. Because of its large size and its definite geographic boundaries, the land drained by Rock Creek and its tributaries lends itself to a natural subdivision for ground-water discussion. The Rock Creek area extends from the Horse Heaven Hills in the north to the Columbia River in the south and its deeply incised drainages produce very rugged relief over most of the basin. The eastern half is largely uninhabited and used mainly for dryland grazing. West of Rock Creek, the area is somewhat less dissected and the flat areas drained by Luna Gulch and Badger Gulch are farmed. In the higher areas to the north, grazing and logging are the primary land uses.

Very little ground-water information is available for much of the Rock Creek area, particularly the eastern and northern part. Virtually no wells have been drilled in these areas and most of the ground water used comes from isolated springs. In the north, the density of springs appears to increase.

A few domestic wells have been drilled in the Pleasant Valley area between Rock Creek and Luna Butte. Most of these are from 100 to 300 feet deep and most furnish adequate domestic supplies. In general, little well irrigation is attempted in the area; however, well 4/18-17K1 was drilled for irrigation purposes. This well is apparently typical of most attempts to secure irrigation water in this area. The well was reportedly deepened twice and is currently about 780 feet deep. It presumably taps aquifers in the Frenchman Springs Member. Currently, the well will sustain a production of 600 gpm for about one day before the pump breaks suction. The owner reports that it is then several days before the well can again be used. The drilling and pumping history of this well characterizes the inadequacy of ground-water supplies for irrigation applications. This undoubtedly is a result of restrictions on recharge resulting from the heavy dissection of the surface by Rock Creek and its tributaries and by the structural discontinuity produced by the Luna Butte anticline.

Goldendale-Centerville Area

In central Klickitat County, the Goldendale-Centerville area consumes the largest quantity of ground water of any area in the county. This area extends from the Horse Heaven Hills to the Columbia Hills and is bounded on the east by Luna Butte and on the west by the main Klickitat River canyon.

The area slopes gently to the south, conforming to the dip of the underlying basalt bedrock, from the Horse Heaven anticline to the Swale Creek syncline near the southern edge of the area. The general flatness of much of the southern part of the area lends itself well to irrigated crops such as alfalfa and wheat. Irrigation and the high population density account for substantial ground-water withdrawal.

Drilling information and borehole geophysics indicate that most of the ground water is obtained from porous interflow zones between the thick flows of the Frenchman Springs Member of the Columbia River Basalt Group. Geophysical logs from wells 4/16-16Q2 and 3/16-18D3 indicate that the interflow zones associated with the Vantage interbed may also be productive. Numerous domestic wells are 200-300 feet deep; however, in many areas much shallower wells provide adequate ground-water supplies. Irrigation wells are somewhat deeper, though few exceed 500 feet in depth and, to date, no wells have been drilled deeper than 1000 feet. Irrigation well production is normally about 500 gpm with a few of the deeper wells capable of producing 1000-1500 gpm.

In the area north and west of Goldendale, where younger volcanics are present, adequate domestic supplies are obtained from the younger volcanics and the underlying sediments. Wells within the younger volcanics must be drilled to depths of several hundred feet to reach water and, in many cases, they probably are drilled into the underlying sediments and/or into Columbia River Basalt. The very coarse, open texture of the younger volcanics apparently facilites rapid vertical movement of water. Incidents of heavy rains resulting in a sudden muddying of water in wells several hundred feet deep have been reported. Whereas the open texture of the younger basalts may reduce their productive capabilities, it probably is beneficial to the underlying aquifers in the Columbia River Group through rapid recharge.

In some areas, the Tertiary-Quaternary sediments present between the Columbia River Basalt Group and the younger volcanics are adequate aquifers. Generally, the productivity of these sediments is directly related to sediment size and sorting and the related permeability. Where the sediments are primarily coarse sands and gravels and are extensive, well productions of up to 150 gpm are reported. In areas where the sediments are predominantly silts, clays, and tuffs, production is poor.

A similar relationship is evident in the Swale Creek valley sediments where many shallow domestic wells yield adequate supplies. Occasionally, wells in the coarse sediments will produce in excess of 100 gpm.

As is the case in the Bickleton area, water-level measurements in the Goldendale-Centerville area reveal considerable information on subsurface hydrology. Water-level contour maps based on mass water-level measurements were constructed. Wells from which measurements were obtained are of varying depths and tap aquifers associated with different stratigraphic intervals. However, with only a few exceptions, all wells have static levels which define a relatively uniform surface and most have static levels within a few tens of feet of the surface. The exceptions are the deepest wells in the area which appear to penetrate a lower system. A good example of the apparent interconnection of producing zones within the upper 500 feet and the abrupt change to the potentiometric surface of a lower zone is illustrated by the hydrogen of well 4/15-16F1 (Figure 64). This well has piezometer tubes set at four different depths and stratigraphic intervals. The top three, representing a total depth of 440 feet, have almost identical static water levels. The

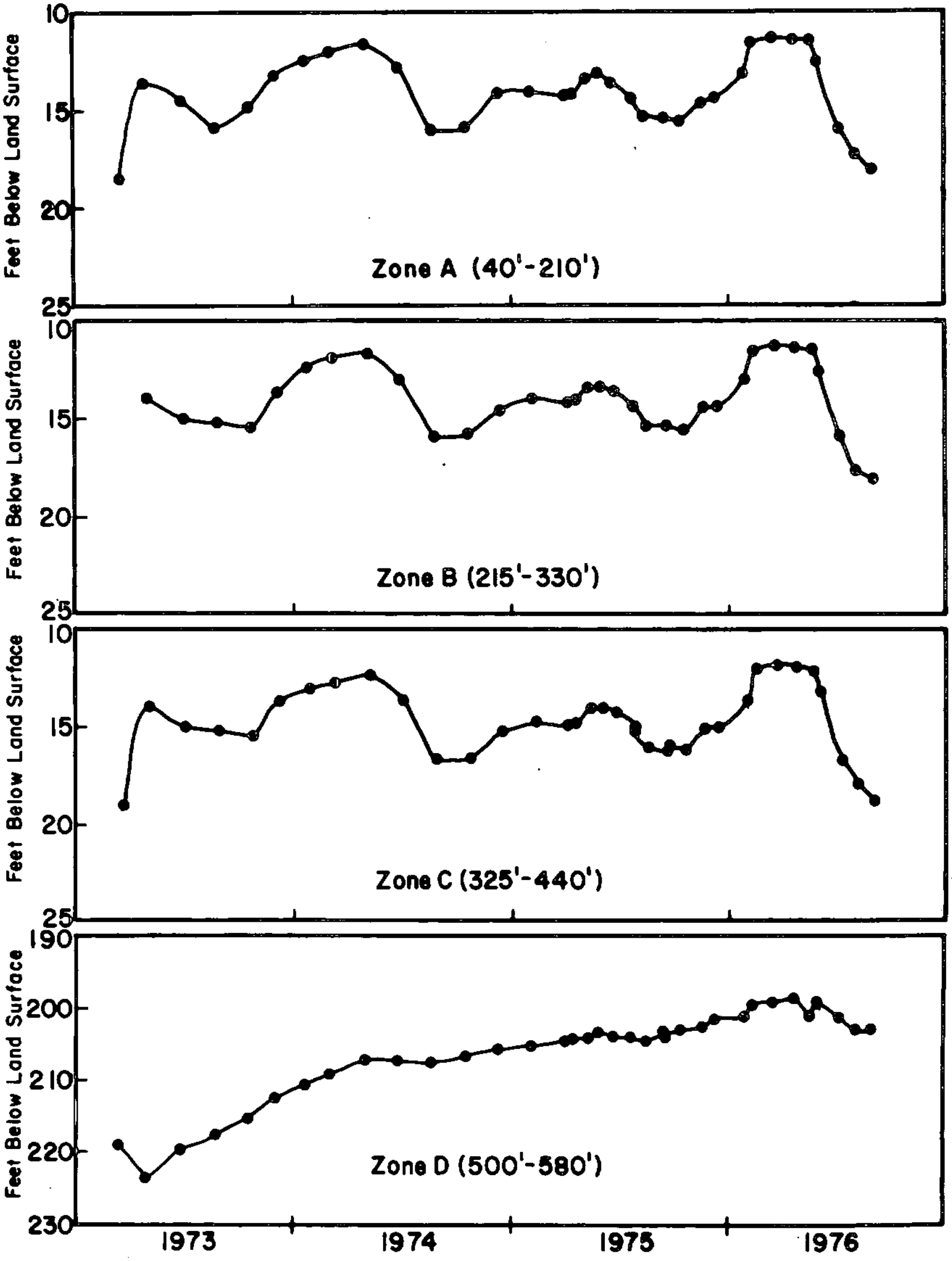

FIGURE 64. Water-level hydrographs, Blockhouse observation well (4/15-16F1), Klickitat County, Washington.

fourth zone (500-580 ft) has a much different water level which is about 200 feet lower than that of the upper three zones.

The mass water-level measurements were taken in early spring and late fall for two successive years, partly in an effort to determine what effect ground-water withdrawals in the Goldendale-Centerville area were having on water levels. Examination of Figures 65 through 68 indicates that although some slight change is noticeable from spring to fall, there is no evidence of a major change. Comparison of these figures with water-level contours prepared by Luzier (1969) indicates that little change has taken place since the mid-1960's when Luzier's data were collected.

The lack of significant changes in the water levels seem to be apparent in both the long-term and short-term hydrographs presented in Figures 69 through 72. Most hydrographs show annual recoveries to levels of the previous years. Even the hydrographs of Figure 72, which represent water-level data collected since 1958, show recovery to common levels each year. These long-term hydrographs do illustrate, however, the effects of increased seasonal withdrawals during the last few years. These effects appear as greater annual fluctuations of the water levels.

Water-level measurements from well 4/16-16F1 appear to be of particular interest (Figure 64). As previously discussed, the water levels associated with the upper three zones appear to conform to those of nearby wells and fit into the contoured surface presented in Figures 65 through 68. Water levels of zone D, however, are much lower and are not directly related to the upper zones. Water-level measurements made of zone D since 1973 indicate a gradual increase in hydrostatic head during the last three years. This head increase is not well understood but may be in response to vertical leakage

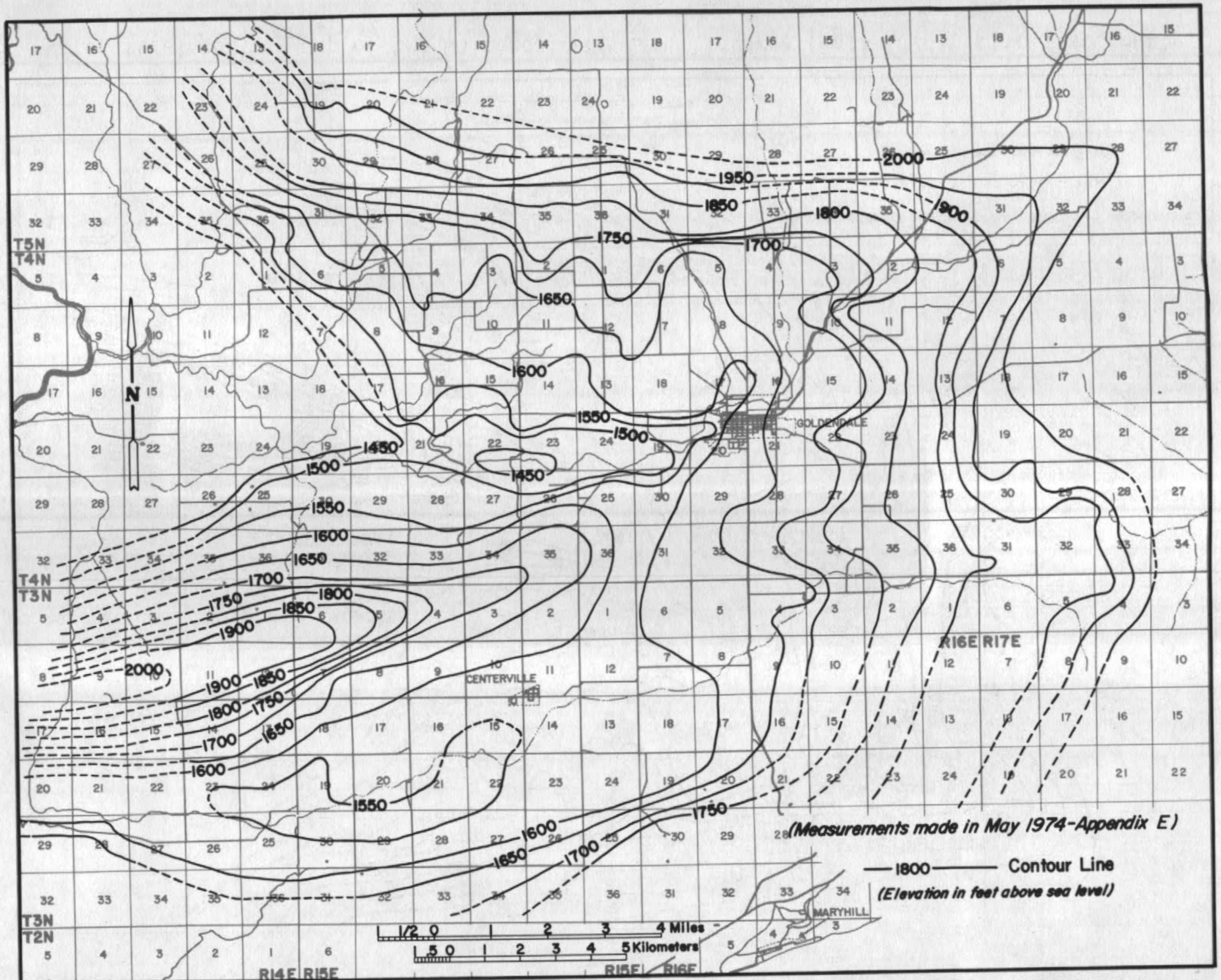

FIGURE 65. Water-level contour map of the Goldendale-Centerville area (Spring 1974), Klickitat County, Washington.

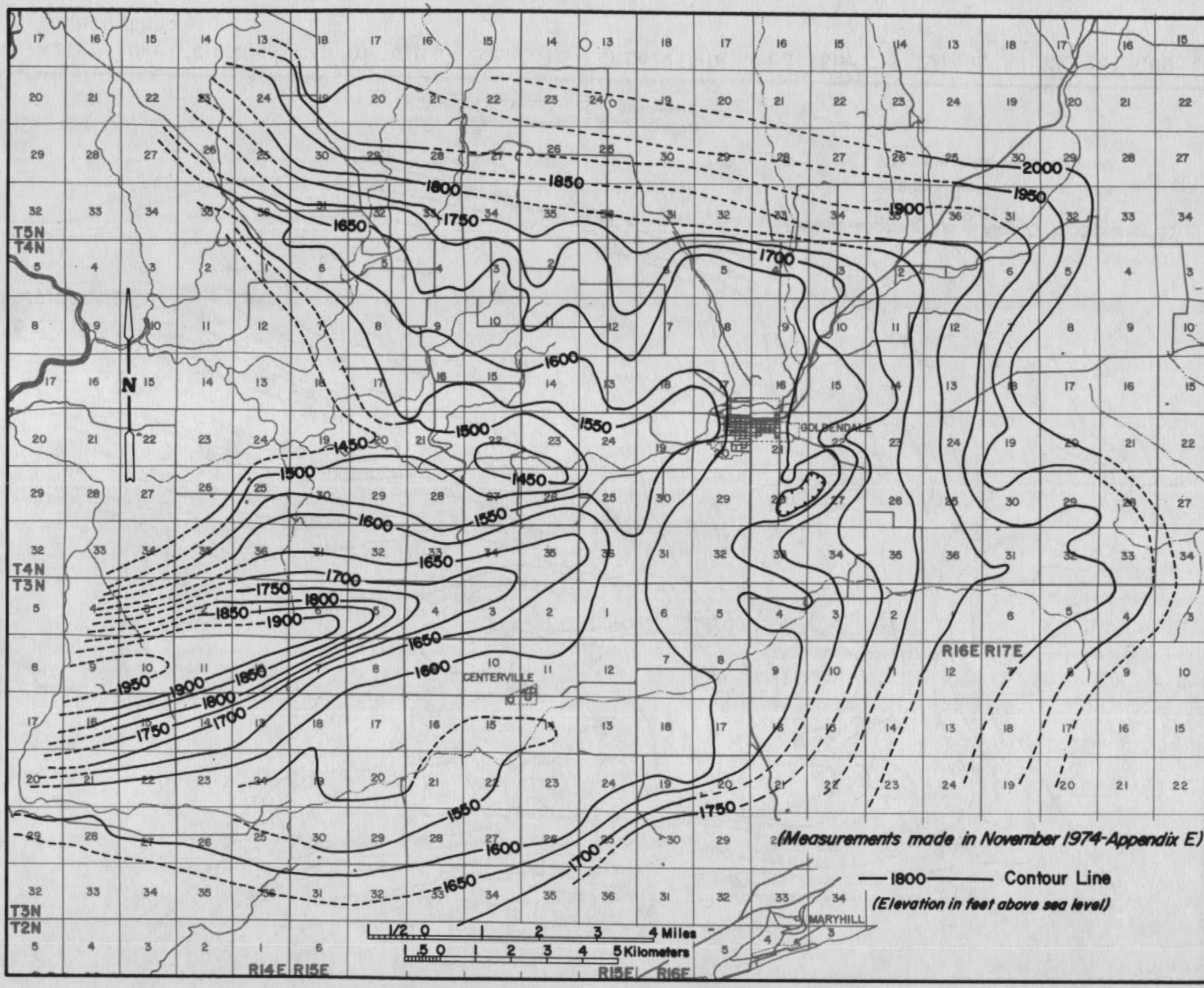

FIGURE 66. Water-level contour map of the Goldendale-Centerville area (Fall 1974), Klickitat County, Washington.

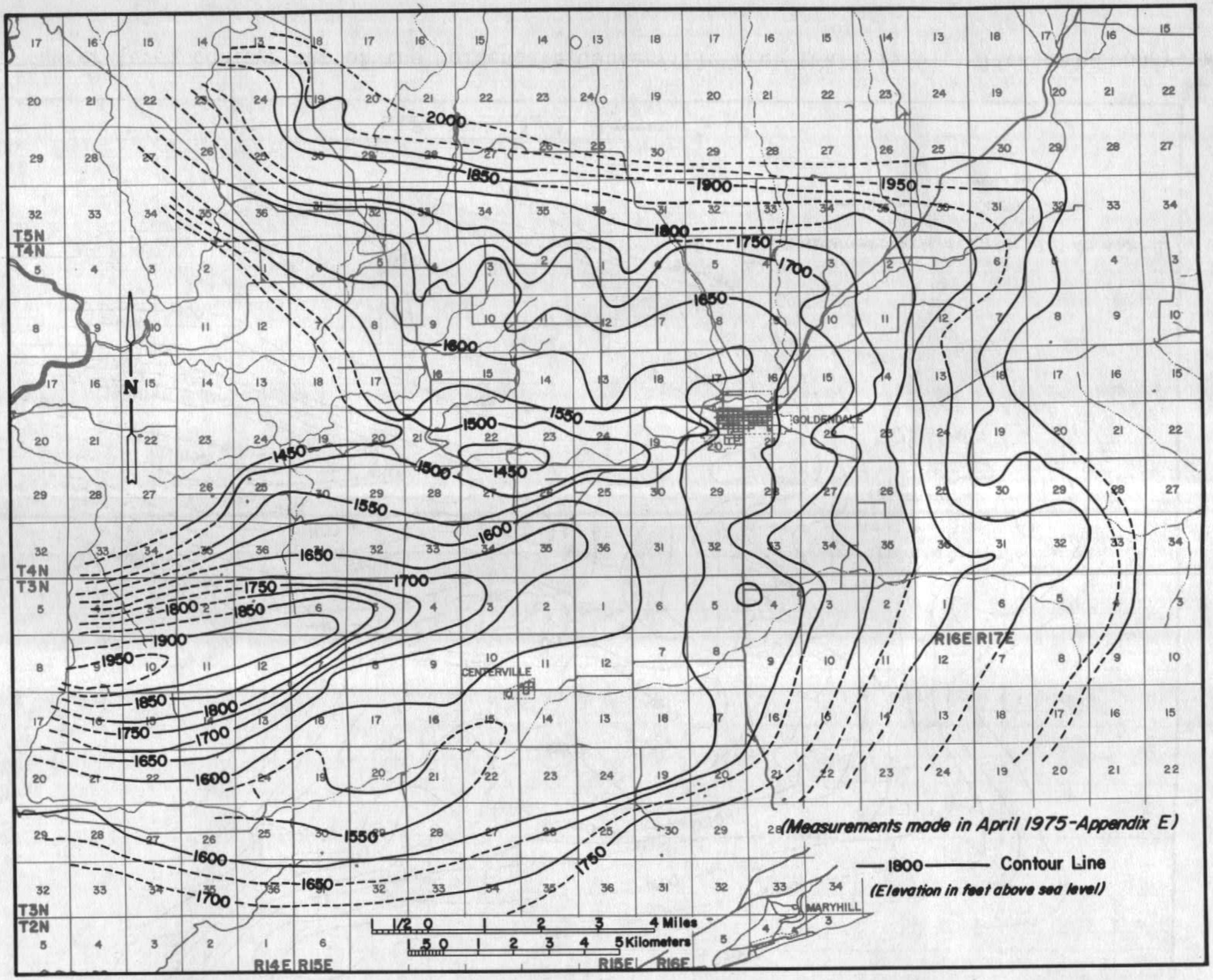

FIGURE 67. Water-level contour map of the Goldendale-Centerville area (Spring 1975), Klickitat County, Washington.

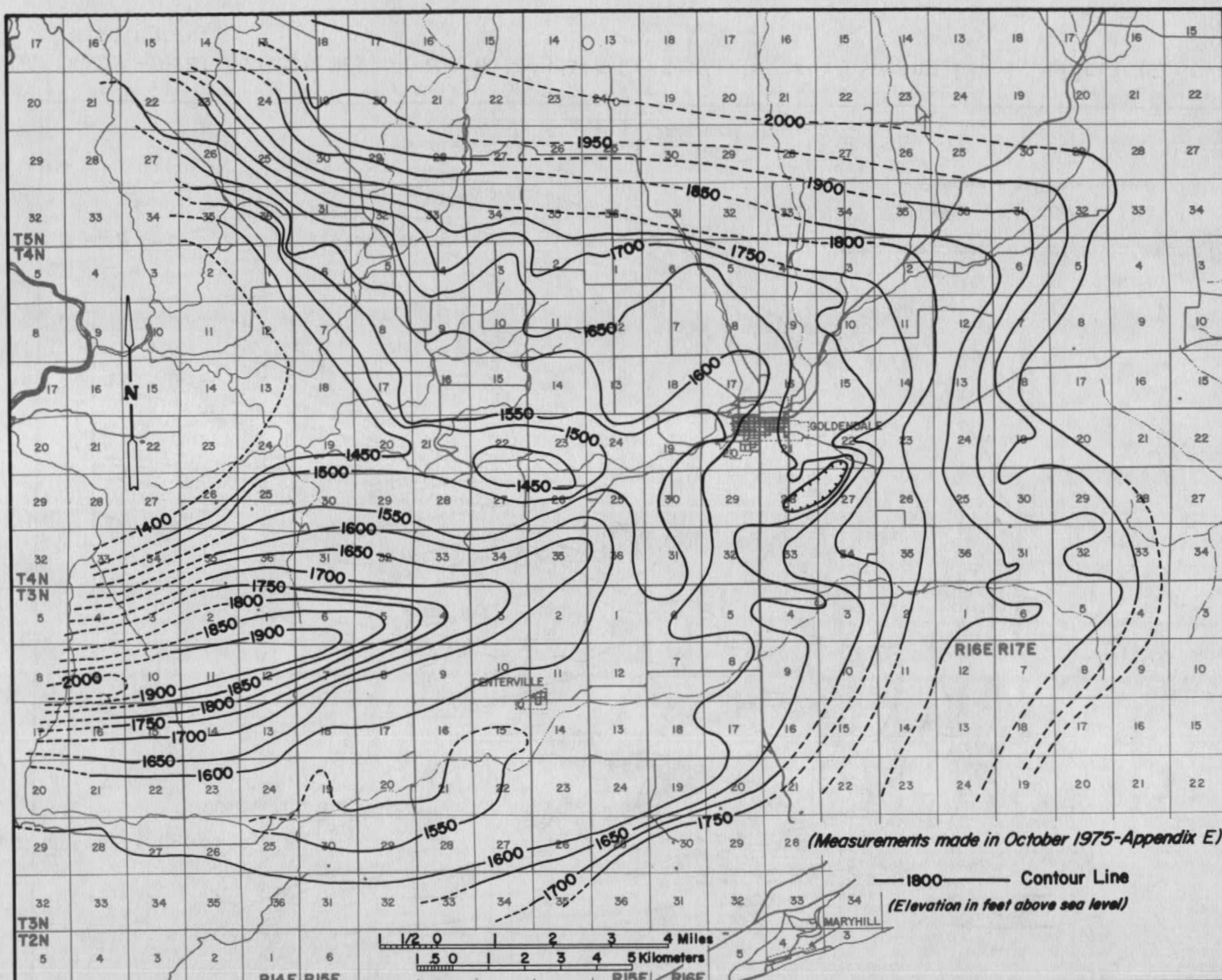

FIGURE 68. Water-level contour map of the Goldendale-Centerville area (Fall 1975), Klickitat County, Washington.

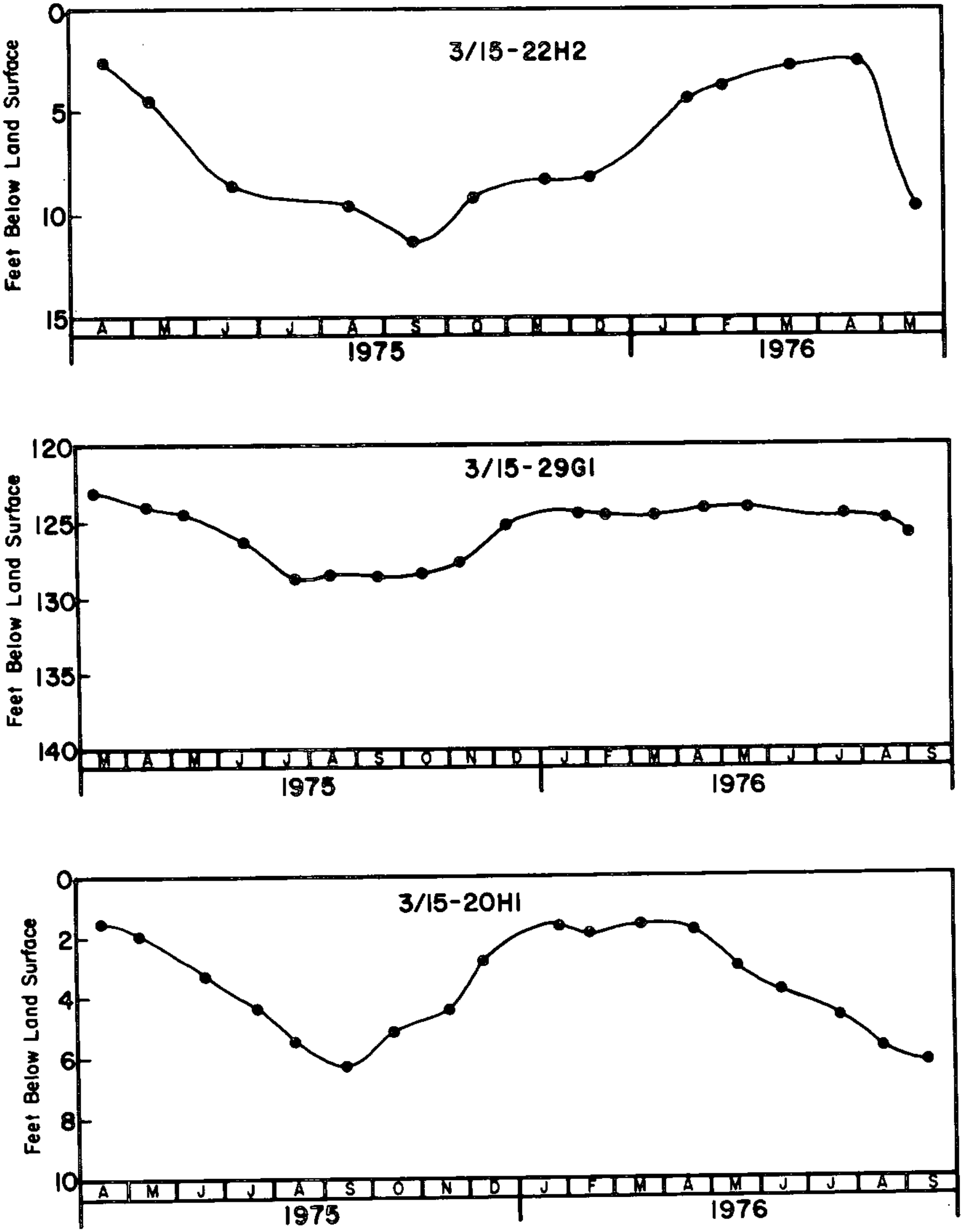

FIGURE 69. Water-level hydrographs, observation wells 3/15-22H2, 3/15-29G1, and 3/15-20H1, Klickitat County, Washington.

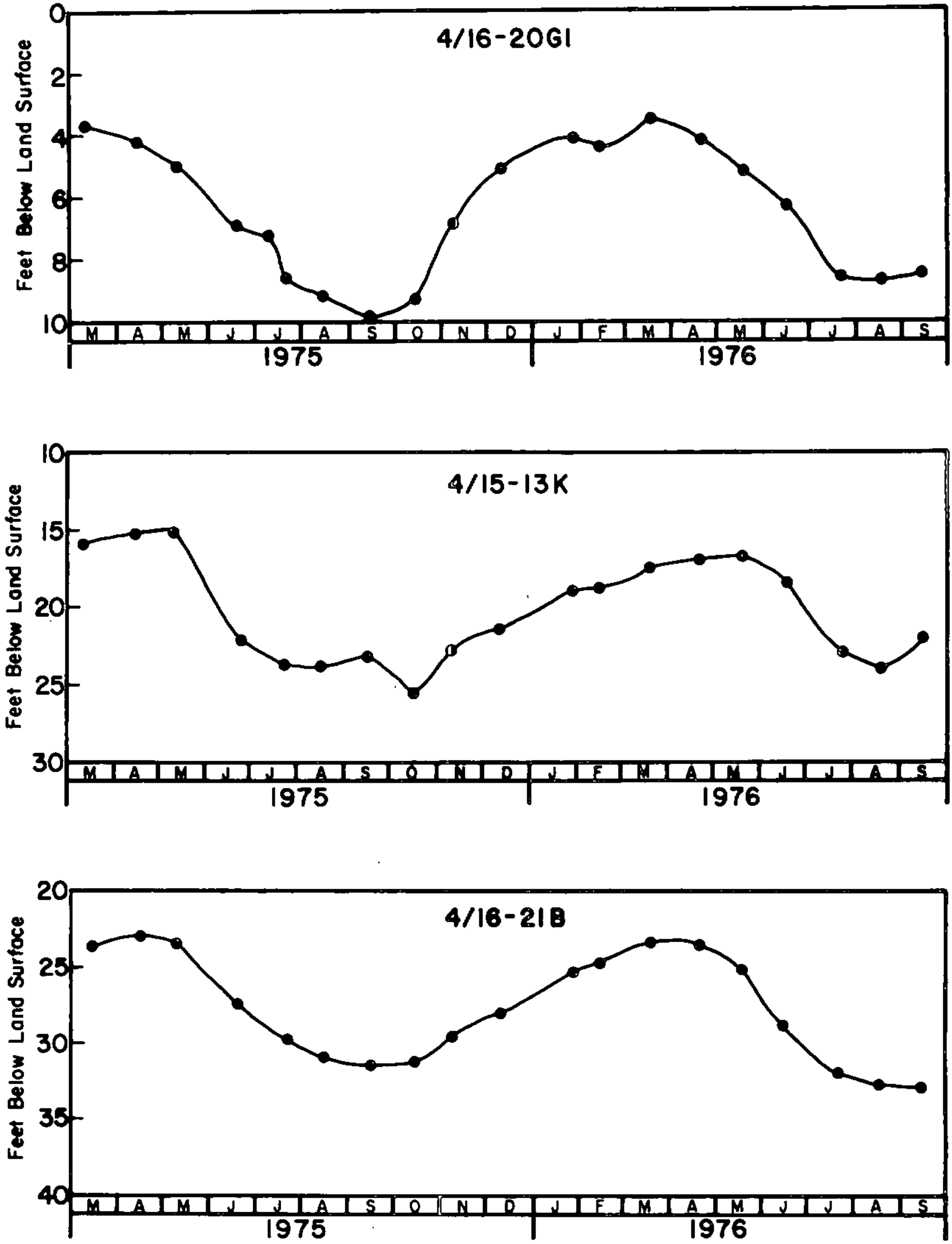

FIGURE 70. Water-level hydrographs, observation wells 4/16-20G1, 4/15-13K1, and 4/16-21B1, Klickitat County, Washington.

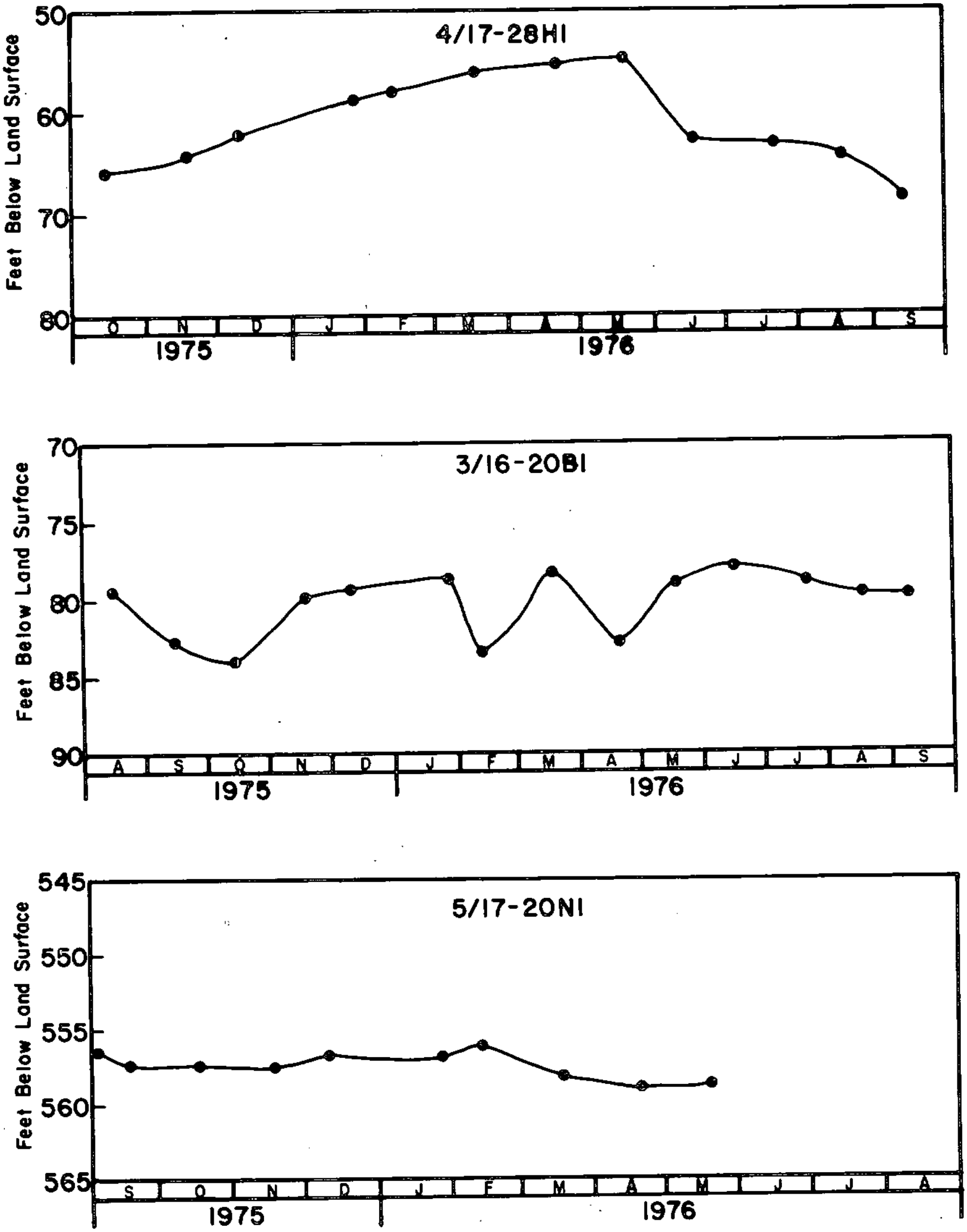

FIGURE 71. Water-level hydrographs, observation wells 4/17-28H1, 3/16-20B1, and 5/17-20N1, Klickitat County, Washington.

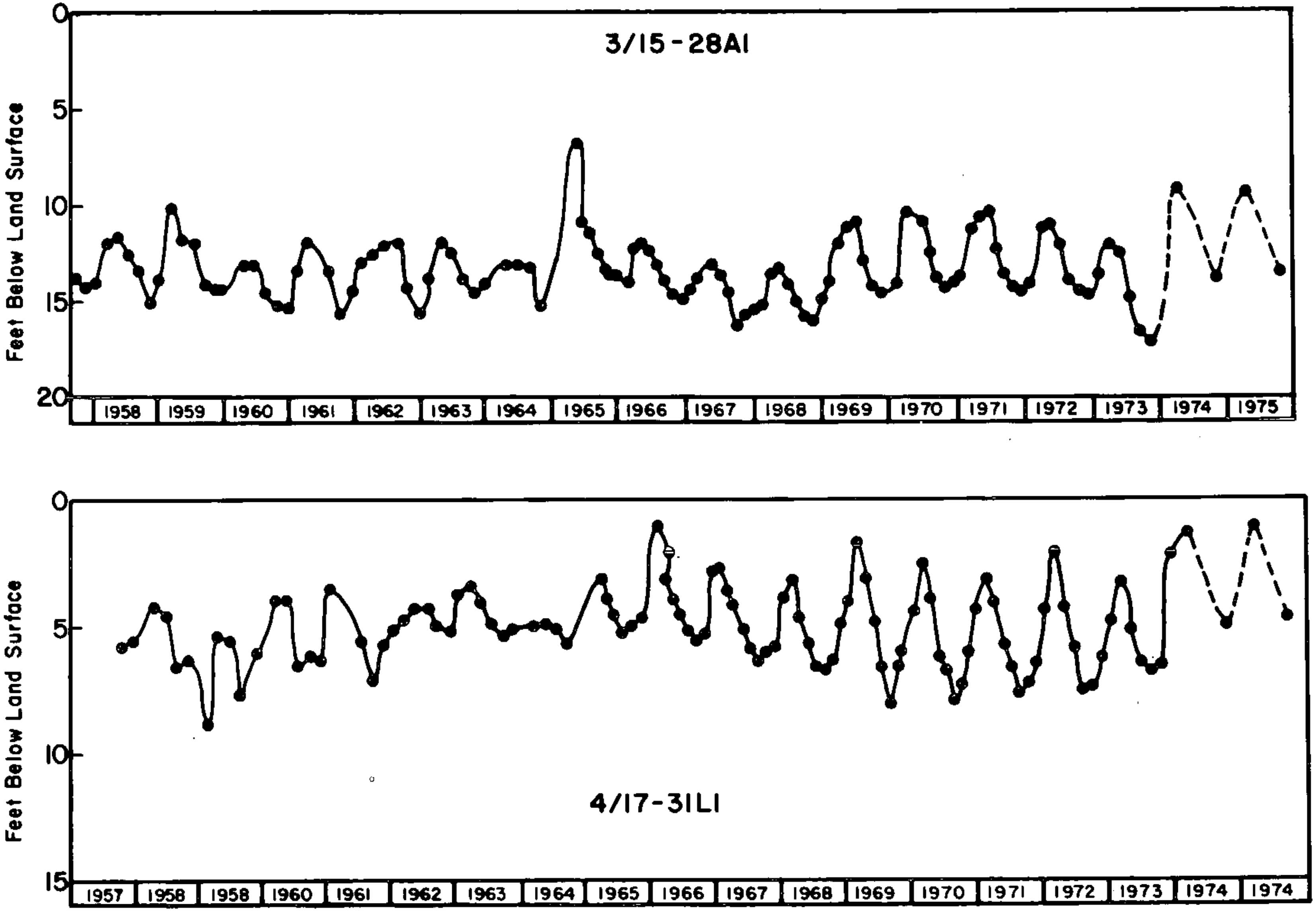

FIGURE 72. Long-term water-level hydrographs, observation wells 3/15-28A1 and 4/17-31L1, Klickitat County, Washington.

associated with the increasing number of wells. The head increase also may reflect a gradual stabilization of the aquifer since well construction.

For some time, the minor northwest-trending structural lineaments of the area were thought to have a significant effect upon the distribution and availability of ground water in the Goldendale-Centerville area. In fact, hydrologic evidence has been used to support the concept that these lineaments are faults. Results of mapping, mentioned earlier, indicate that these structures are folds and that there is little direct evidence of faulting. Borehole geophysical logs of wells in a line perpendicular to the trend of lineament reveal little evidence of structural or hydrologic discontinuity except in the immediate area of the small anticlinal folds. The geophysics indicate no vertical offset of stratigraphic units and show that vertical fluid movement between the same zones is characteristic of wells on either side of one of the projected lineaments. Similarly, contouring of the mass water level information suggested that the contour lines crossed the lineaments without interruption.

While the structures do not appear to have a substantial effect on the hydrology of the area, some local subsurface damming may occur in the immediate proximity of these folded structures. Well 4/15-26A1, a flowing well at the base of Snipes Butte, may reflect such a local damming effect. Several other wells in this area flow intermittently, however, and the flow may be attributable to well-head elevations that are lower than the regional water surface during recharge months.

A group of flowing artesian wells is present in the Little Klickitat canyon, northwest of Goldendale, in Sections 2, 10, and 11 of T. 4 N., R. 16 E. The reason for the high heads in these wells is not fully understood. However, it may result from a combination of the low elevation of the valley relative to the surrounding area, and to the presence to the south (down gradient) of an apparent deep channel filled with younger volcanics.

In general, adequate supplies of ground water are available in most locations of the Goldendale-Centerville area. Production is poor in some of the younger volcanics near Goldendale, apparently because of the restricted nature of the younger basalts. Other areas where well production does not seem adequate are the Horseshoe Bend area west of Goldendale and the High Prairie area between the Swale Creek and Klickitat River canyons. Production in these areas is poor probably because they are isolated by relatively deep canyons. This isolation limits aquifer continuity and restricts recharge to only that available within the area.

For most of the Goldendale-Centerville area, adequate domestic and irrigation supplies can be obtained a few hundred feet below surface in the Frenchman Springs Member. In many areas, irrigation wells between 500 and 1000 feet in depth have produced 1000 to 2000 gpm. This is particularly true of the Swale Creek valley near the axis of the Swale Creek syncline.

Camas Prairie-Upper Klickitat Basin Area

Camas Prairie consists of unconsolidated sediments, primarily gravel, sand and clay, which overlie volcanic bedrock. Total thickness of these deposits is not known; however Cline (1976) reports them to be about 100 feet deep in the southern part of the prairie. The age and nature of the underlying bedrock is not known; however, outcrops surrounding the Camas Prairie include both Columbia River Basalt and younger olivine basalt, and it seems likely that these same rocks are present beneath the sediments.

Ground-water use in the Camas Prairie area is restricted principally to domestic and stock-water needs. Pastures are extensively irrigated, but this water is obtained from tributaries to the Klickitat River delivered via Hellroaring Ditch.

There are numerous small springs in the hills surrounding the prairie and several large springs along the lower reaches of Outlet Creek and in the Klickitat River Canyon just north of its confluence with Outlet Creek. Cascade Spring (6/13-10R/s) reportedly discharges 18,000 gpm into Outlet Creek and with several other nearby springs combines to produce about 100 cfs increase in the flow of Outlet Creek (Cline, 1976). Several large springs on the east side of the Klickitat River also produce substantial quantities of water and supply the state salmon hatchery east of Glenwood. McCumber Spring (3-1/2 miles north of Glenwood) has been developed as a water supply for the Glenwood area and is estimated to yield about 1800 gpm.

The numerous springs and abundant surface-water resources have limited well drilling in the Camas Prairie area. In addition, development of a water system in the Glenwood area and recent expansion of the Conboy Wildlife Refuge have resulted in the removal of many existing wells from active service.

Wells on Camas Prairie normally obtain water from either the unconsolidated sedimentary deposits or the underlying basalt aquifers. The variable nature of the unconsolidated sediments results in highly variable permeabilities and a wide range of production capabilities, reported by Cline (1976) to vary from 0 to 500 gpm. Cline suggested that in some areas production in excess of 500 gpm might be obtainable for limited time periods. In many areas, shallow wells dug in the sediments produce adequate domestic supplies.

The aquifer system underlying the unconsolidated sediments is associated with the basaltic bedrock. As is the case elsewhere in the basalts, ground water is normally obtained from interflow zones between basalt flows. To date, most of the production from the basalts of the prairie has been for domestic and stock use and is moderately small. It seems likely, however, that large production could be obtained from the basalt aquifers should it ever become desirable.

The occurrence of two distinctively different producing materials in the Camas Prairie area brings about two distinctive hydraulic systems. Water levels in area wells depend upon which system the well penetrates. Two observation wells were established in Glenwood to monitor the two systems. Well 6/12-10P1 is a shallow dug well, the hydrograph of which (Figure 73) reflects the annual fluctuations of the water level in the unconsolidated deposits. The somewhat bimodal appearance of the well hydrograph probably reflects recharge occurring with the start of the irrigation season. In general, water levels of wells in the unconsolidated sediments are within a few tens of feet of the surface.

Well 6/12-10K1 derives water from the underlying basalt and its water level is indicative of the deeper wells. Cline (1976) reports the water surface of this lower aquifer system to be at an elevation of about 1700 feet with a gentle slope to the north and east. Examination of the hydrograph of 6/12-10K1 in Figure 73 reveals that, in contrast to many wells, the water level rises to its highest point during the late summer months and, conversely, reaches its lowest point in mid-winter. This may be a result of the lag time involved for annual changes in precipitation to be reflected in the deeper system. The well also may be responding to recharge from irrigation in the area which would be active during the summer months and discontinued during the winter. Study of the well hydrograph indicates that an apparent overall decline in the water level occurred during the three years in which water-level measurements were made. Whether this is indicative of any long-term trend is not known, but with the amount of precipitation available to

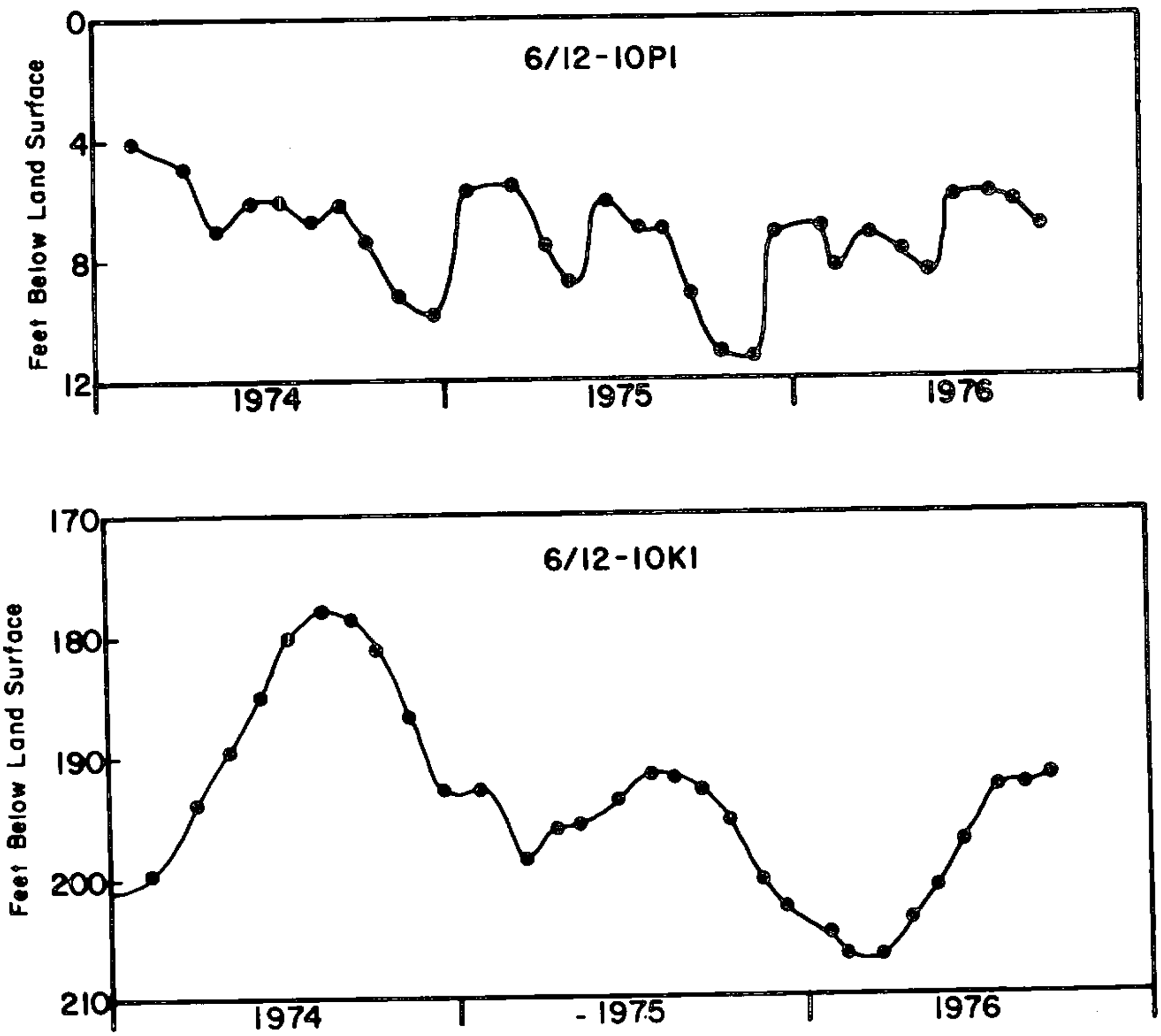

FIGURE 73. Water-level hydrographs, observation wells 6/12-10P1 and 6/12-10K1, Klickitat County, Washington.

the area and the relatively low ground-water withdrawal, it seems unlikely. Instead, the water levels may be reflecting a decrease in recharge related to a reduction in irrigation because of the wet summers of 1974 and 1975.

In general, the Camas Prairie area enjoys an abundance of ground- and surface-water supplies. In many areas, springs provide adequate domestic and stock water. Elsewhere, wells can furnish needed water supplies from either the unconsolidated deposits or the underlying basalt aquifers.

Western Highlands

Ground-water distribution and production in the western highlands is highly variable. In some areas, particularly in the northeast part of the highlands, numerous springs exist. Most of the springs have low discharges and are used primarily for stock watering. Other springs occur in the canyon areas of Major Creek and Jewett Creek and in lesser drainages. With these exceptions, springs appear to be less numerous in the highlands than in the Camas Prairie area directly to the north.

Most domestic water in the highlands is obtained from wells, although production does not appear to be as good in the highlands as elsewhere in the western part of Klickitat County. Most of the ground-water production comes from interflow zones within the Columbia River basalt; however, production is also obtained from the younger volcanics in the northeast and west. Wells in the highlands vary considerably in depth and production; however, in general, wells with depths of 200 to 300 feet, producing less than 10 gpm, are common. Reasons for the apparently restricted availability of ground water in the highlands are not evident. However, a combination of geologic structure, erosional dissection, and limited recharge are suspect.

Large-scale irrigation is virtually nonexistent in the western highlands although there has been some recent interest evident in the Laws Corner area northeast of White Salmon. To date, well production is small; however, one well, 3/11-15B1, produces 100 gpm from a depth of 185 feet. It is not known whether deep well drilling would develop large supplies in the area. Nevertheless, limitations inherent to the local dissection and limited recharge suggest that production in excess of 200 to 300 gpm would be minimal. Furthermore, declining water levels with depth, characteristic of this area, indicate that most attempts to obtain water from greater depths would result in correspondingly lower water levels.

Lower Klickitat River Valley

Geologic units in the lower Klickitat valley are restricted to basalts of the Columbia River Group and recent stream gravels deposited at wide spots in the valley. Ground-water occurrences within the valley are limited to springs issuing from joints, faults, and interflow zones within basalts and to wells drilled into the gravels or the basalts. Demand for the ground water is small, with most being for domestic purposes.

Most ground-water production is from shallow wells in the gravels or the basalts. Where sufficiently large gravel bars exist at a relatively safe elevation above the current river channel, most water is obtained from shallow dug or drilled wells in the gravels. Where the canyon is so narrow as to preclude formation of gravel bars, water is obtained from shallow wells drilled into the basalts. Because of the proximity to the river, most basalt wells are less than 100 feet deep.

Most of the large springs and deep wells exist in a unique ground-water area between Klickitat and Wahkaicus. Here, early settlers found several large springs (Klickitat Springs) with a high mineral content and charged with carbon dioxide. During the first half of this century, carbon dioxide was extracted from this water, and dry ice was manufactured. In addition, for short periods of time, the water was bottled and sold.

Several wells drilled at a later time encountered water of similar quality. Most of these wells were drilled to depths between 200 and 300 feet, and several are free-flowing. Evidence of the dry ice operations can still be seen along the highway south of Wahkaicus in what is now a fishing access area administered by Washington State. Flowing wells are still in existence here. Reasons for the unique ground-water occurrence are not fully understood, but Newcomb (1969) and Luzier (1969) have attributed it to faulting which provides a conduit for deep, warm highly mineralized waters to rise to the surface.

White Salmon River Basin

Basalts of the Columbia River Group are exposed on the sides of the White Salmon River basin and younger volcanics fill the valley bottom. The thickness of these younger volcanics is not known although it is likely that they are underlain by the older Columbia River Group and, in some areas, by older volcanics.

Like the Camas Prairie area, the White Salmon basin enjoys abundant ground-water resources. Numerous springs issue from the older basalts along the sides of the basin and from contact zones and fractures within the younger volcanics. Hydrographs of the White Salmon River indicate a gentle recession limb for the station at Underwood, which is attributed to the significant contribution of ground water in the central part of the basin. Much of this contribution is from springs around the BZ Corners area. Springs are also abundant in the Trout Lake area, and part of that community's water supply is taken from Bear Spring west of the town.

Development of ground-water resources through wells is restricted primarily to the immediate White Salmon valley, in those areas where springs or surface supplies are not available. In most cases, wells are relatively shallow, often being less than 100 feet in depth, with yields rarely exceeding 50 gpm. Wells in the valley normally tap interflow zones within the younger volcanics or in the underlying Columbia River Basalt.

In the northern part of the basin, near the town of Trout Lake, fewer wells exist because the well-established Glacier Springs water system provides domestic water to many of the houses. Information from the few wells in the area indicates a situation similar to that in the lower valley where domestic supplies are relatively easy to obtain.

One observation well (4/10-24J2) was monitored in the White Salmon valley near Husum and is probably typical. The well is 93 feet deep and terminates in an interbed within the younger volcanics. The well hydrograph, Figure 74, indicates a static level within 25 feet of the surface and relatively little annual variation. Most wells within the valley are similar, although wells drilled higher on the basin sides are likely to be somewhat deeper and may have lower water levels.

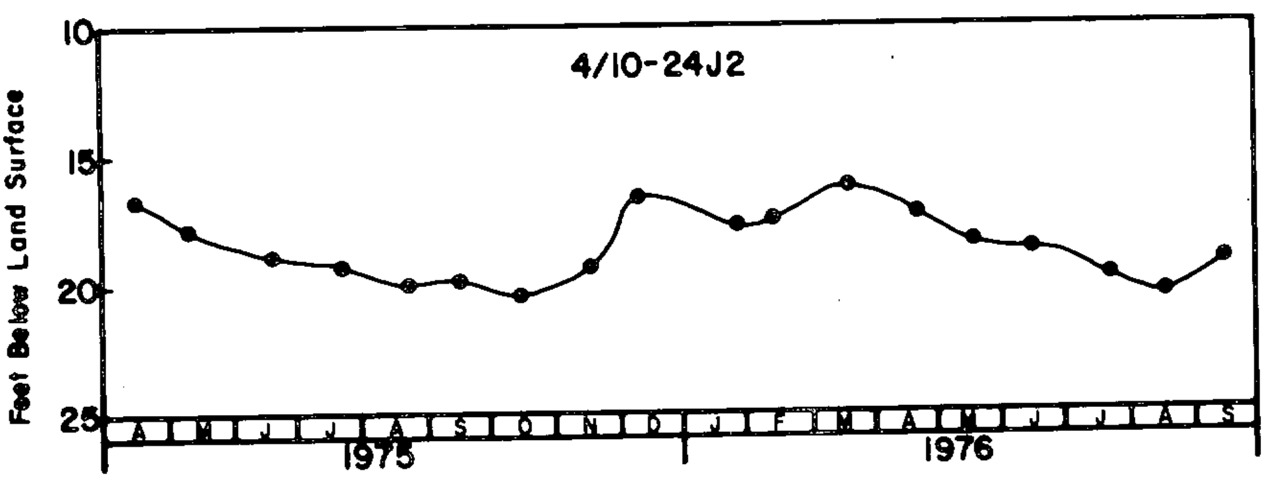

FIGURE 74. Water-level hydrograph, observation well 4/10-24J2, Klickitat County, Washington.

There is much interest in irrigation among orchardists and farmers, and it seems likely that well irrigation within the valley would be feasible. To date, no large-volume well exists, but drilling to depths in excess of 500 feet in the central valley might provide significant quantities of irrigation water.

Columbia River Gorge

The Columbia River gorge is incised into basalts of the Columbia River Group and the river flows on the basalt surface. Younger volcanics are virtually absent in the gorge except for isolated deposits related to Haystack Butte (Sec. 3, T. 2 N., R. 15 E.) which lie on the north side. In the western half of the gorge, deposits of Tertiary-Quaternary sediments, mainly tuffs and tuffaceous sands and silts, are present along the sides. These deposits tend to increase in thickness and quantity westward. Other deposits in the gorge include unconsolidated sediments, consisting mainly of glacial fluvial gravels, sands, and silts related to glacial flooding and lacustrine sediments.

Within the gorge, ground water is used primarily for domestic and municipal needs; irrigation water is generally obtained from the Columbia River. The occasional occurrences of springs in the gorge appears to be controlled predominantly by effective precipitation and geologic structure. Because of precipitation decreases in the gorge from west to east, more springs occur along the western than the eastern part of the gorge.

Although few springs with substantial discharges appear along the eastern half of the gorge, there are many small seeps and intermittent wet areas, many of which have been developed into stockwatering ponds by area ranchers. These seeps occur at interflow zones within the basalts and in fractures or joints where an avenue for ground-water discharge is available. A few springs of constant discharge occur where faults or folds have produced a ground-water conduit. An example of such a spring can be seen along Highway 14 in SE 1/4, Sec. 8, T. 3 N. R 18 E. where a spring large enough to provide domestic water occurs in a large breccia-gouge zone associated with a fault.

To the west, springs become more abundant and, as Newcomb (1969) indicated, these are controlled to some degree by the steepness of the slope. Greater numbers of springs tend to occur on the gentler slopes. Newcomb indicates that spring density in the central part of the area, northeast of Lyle, is on the order of one spring per square mile. Discharge of most of these springs is low, from 1 to 10 gpm; however, he reports isolated instances of flows on the order of 30 gpm. Springs become more common and yields greater as one moves westward toward the Bingen area.

Much of the ground water within the gorge is obtained from wells. In the eastern half of the gorge there are few wells and most are located in and around Roosevelt. Of several irrigation wells located in Sec. 21, T. 3 N., R. 20 E., most are shallow (less than 300 feet deep) and produce from 100 to 1000 gpm. Water levels in many of the wells indicate a degree of hydraulic interconnection with the nearby river, and it is likely that substantial supplies could be developed in the area.

Water supplies in the Goodnoe Hills area are generally marginal. Most wells are drilled to depths of 200-300 feet and yields are often less than 10 gpm. The probable reason for the lack of abundant ground-water supplies relates to the area's geologic and geographic position. The Goodnoe Hills area is situated on a level bench about half-way between the Columbia River and the crest of the Columbia Hills and is bisected by Rock Creek canyon. The size and location of the area suggests that it receives a limited amount of recharge and it is unlikely that large quantities of ground water will ever be obtained from wells in the Goodnoe Hills area.

Measurements from observation wells in the Goodnoe Hills area (Figure 75) indicate that although water levels are often greater than 100 feet below surface, there is little evidence of overall decline. This lack of apparent decline may be attributed to the limited production of the area and the resulting limited demand upon the area's ground-water supplies. Well 3/20-7F1 is located in Rock Creek Canyon and the water level in this well is much closer to the surface than the wells on the plateau surface. The hydrograph of this well (Figure 75) indicates good annual recovery in this area.

Near the John Day Dam an aluminum plant operated by the Martin Marietta Corporation obtains ground-water supplies from deep wells within 0.25 miles of the river. The plant requires substantial quantities of water and two of their wells (3/17-20K1 and 21C1) were drilled to 1000 or more feet. In spite of the proximity to the river, production of these wells is somewhat limited, and one (3/17-21A1) has been removed from service because of inadequate production.

In the Dallesport area, a number of wells have been drilled for irrigation and domestic supplies. Most are less than 200 feet deep and produce less than 200 gpm. Three deeper wells (2/15-22F1, 22P1, and 27B1) produce 700 to 1000 gpm.

In the Dallesport-Dalles area, a highly productive ground-water body called the Dalles Ground Water Reservoir provides the city of The Dalles with part of its municipal supply. This reservoir occupies an area of about 30 square miles which underlies The Dalles and the Columbia River. The reservoir produces abundant quantities of ground water from interflow zones about

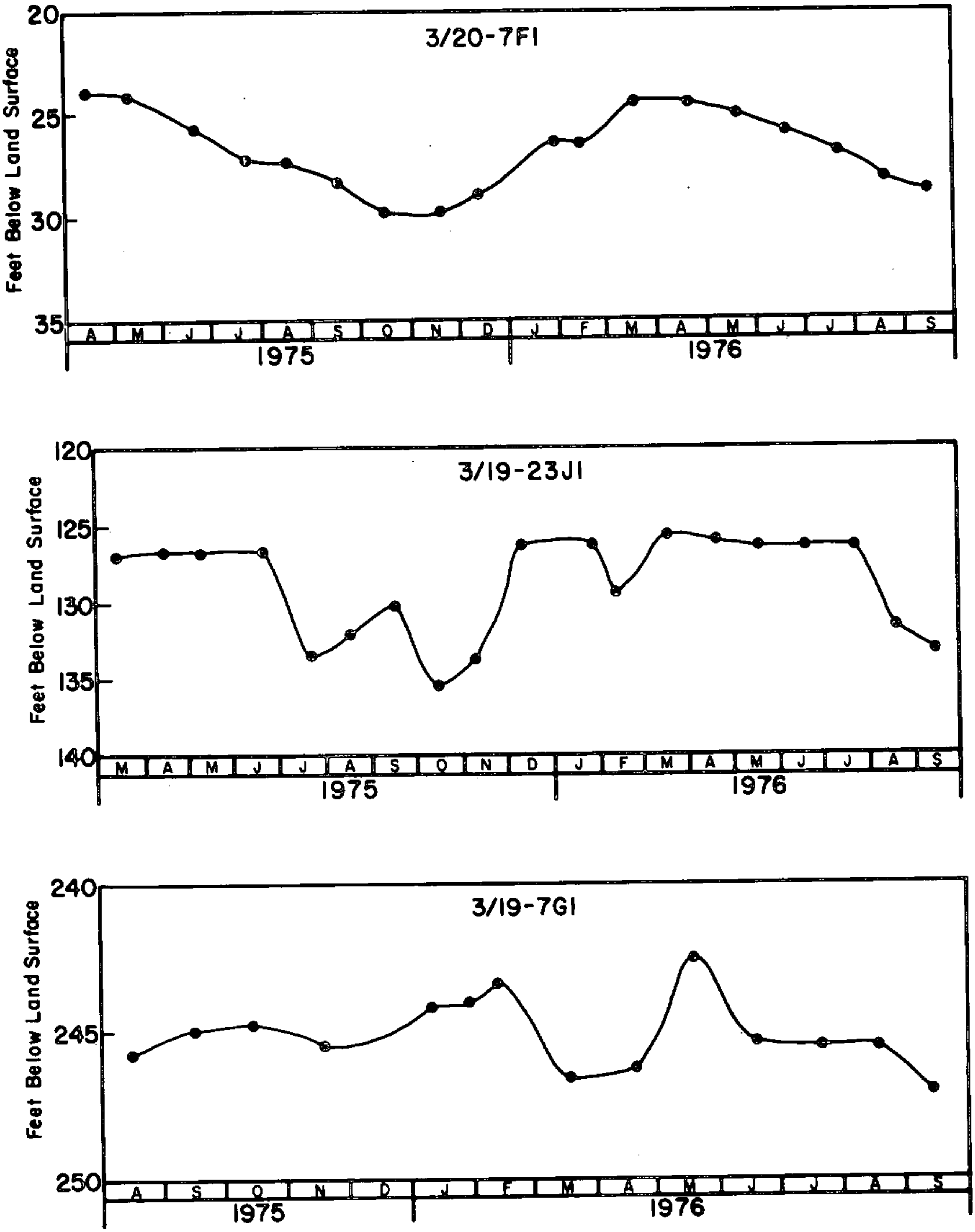

FIGURE 75. Water-level hydrographs, observation wells 3/20-7F1, 3/19-23J1, and 3/19-7G1, Klickitat County, Washington.

100 feet below sea level. Newcomb (1969) showed that wells in a part of the Dallesport area in Klickitat County also tap this ground-water body.

The Dalles Ground Water Reservoir is of considerable interest because it is an important municipal source for The Dalles and because there has been evidence of continued water-level decline in wells tapping this system. Early measurements in wells showed the water level of the reservoir to be about 77 feet above sea level (Piper, 1932). Construction of the Bonneville and later The Dalles dams raised the river level; however, in spite of the immediate proximity of the reservoir to the river, water levels of the reservoir wells did not respond. In fact, Newcomb (1969) reported a continued decline in the water-level elevation which reached 28 feet in 1964. Newcomb estimated a decline rate of about 5 feet per year for the reservoir.

Examination of water levels from The Dalles city wells and conversations with officials of the Oregon State Water Resources Division indicate that the problem of declining water levels may have changed. Water levels in several

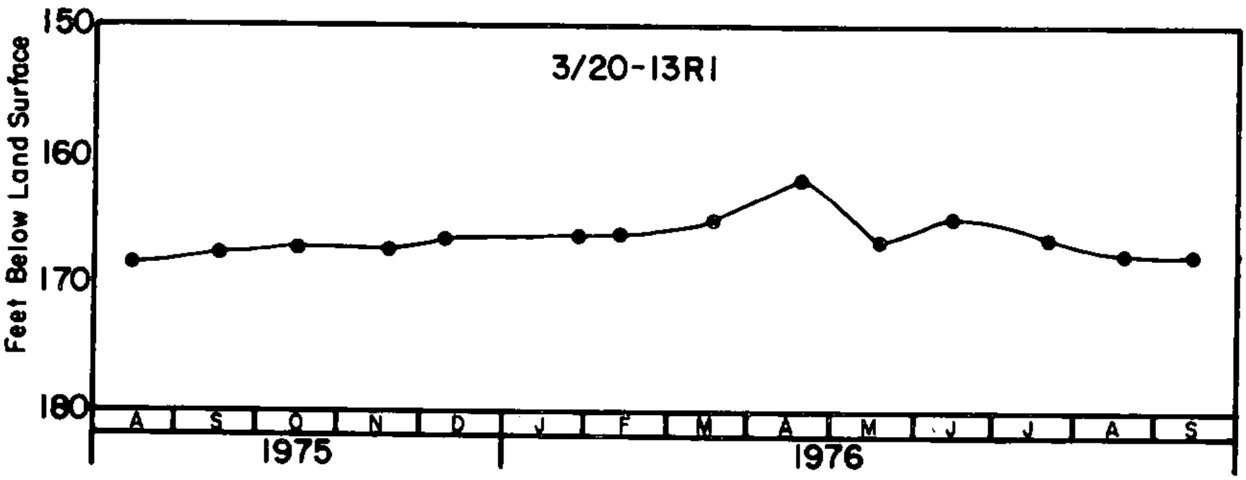

FIGURE 76. Water-level hydrograph, observation well 3/20-13R1, Klickitat County, Washington.

wells along the Columbia River now appear to be rising in response to the higher river level. In addition, water levels in The Dalles municipal wells which tap the reservoir reached elevations between 20 and 40 feet in March of 1977. This would suggest that levels have remained relatively constant since the late 1960's.

WATER QUALITY

Water quality is a function of the amount of material dissolved or suspended in the water. In general, the higher the amount of dissolved and suspended matter the poorer is the quality of the water. However, lack of certain elements, such as oxygen, can also contribute to poor water quality. Recently it has become apparent that many industrial, domestic, and recreational practices have a profound effect upon water quality. With the increased demand on water resources for agriculture, industry, and domestic uses, monitoring of water quality has become increasingly important.

To facilitate determination and maintenance of water quality, a series of water quality standards has been established. These standards are generally presented as the maximum or minimum amounts of dissolved or suspended material which will not be detrimental to public health or to the life-sustaining and aesthetic qualities of a water source.

Discussion of the water quality of Klickitat County is divided into surface-water quality, which deals primarily with the major rivers, and groundwater quality which includes springs and wells. Surface-water quality data is a compilation of analyses done by the U. S. Geological Survey. Ground-water quality information was assembled from previous studies of selected areas within the county. No original water quality analyses were made in this study.

Surface-Water Quality

Much of the county is semiarid and lakes are virtually nonexistent. Thus, information on surface-water quality in Klickitat County is restricted largely to perennial rivers and streams. A compilation of the availability of surface-water quality data is presented in Table 5. Locations of the sampled sites, presented in Table 5, are shown on Plates I, II, and III. It can be seen that little long-term water quality information exists. The most continuous chemical analyses available are for the Klickitat River near Pitt and the White Salmon River near Underwood. Selected parts of these analytical data are presented in Appendix F. The complete analyses are available in the yearly water quality summaries published by the U. S. Geological Survey and in Van Winkle (1914) and Santos (1965). In addition, partial listings of chemical analyses from streams in the Glenwood-Camas Prairie area and from the Little Klickitat River near Wahkaicus are presented in Santos (1965). Analyses for the remaining stations in the Glenwood area are available in the 1974 edition of Water Resources Data for Washington, Vol. 2, Water Quality Records.

Specific Properties and Constituents

Records indicate that the number and type of water quality properties and constituents tested have varied considerably with time and sampling site. Therefore, only the few properties and constituents which are repeated frequently and which are good indicators of stream quality were chosen for presentation and discussion. These properties and constituents are temperature, conductivity, pH, dissolved oxygen, dissolved solids, total nitrate, and total coliform. A discussion of each is presented below.

Temperature

Water temperature, when combined with other properties and constituents, provides an indication of water quality. Warmer water tends to increase the rate of biological reactions and results in excessive oxygen depletion. Loss

TABLE 5: Availability of surface-water quality data, Klickitat County and upper Klickitat River basin, Washington.

Gaging Station	U.S.G.S Number	Daily Temperature	Daily Suspended Sediment	Periodic Chemical Analyses
Alder Creek at Alderdale	14034350	1962-1966	1962-1968	
Rock Creek near Roosevelt	14036000	1962-1968	1962-1968	
Klickitat river below Soda Springs Creek	14108200			1974
Big Muddy Creek	14109000			1974
Klickitat River near Glenwood	14110000	1950-1956, 1970		1959
Trout Creek	14110480			1974
Elk Creek	14110490			1974
Outlet Creek above Outlet Falls	14110720			1974
White Creek	14110800			1974
Summit Creek	14111100			1974
Klickitat River near Dead Canyon	14111500			1974
Little Klickitat River near Wahkaicus	14112500			1959
Klickitat River near Pitt	14113000	1950-1970		1910-1911, 1959, 1966-1975
White Salmon near Underwood	14123500	1968-1970		1960-1973

of oxygen can cause an overall decrease in water quality. In addition, the ability of water to dissolve material is temperature-dependent, and a warm stream normally will contain a higher concentration of dissolved solids.

Conductivity

Conductivity is the ability of water to conduct electricity. Since conductivity is directly related to the amount of dissolved material present in the water, it can be used as an indicator of dissolved solids and water hardness; high conductivity values indicate a high content of dissolved material.

pH

pH is a measurement of the acidity or alkalinity of water and is based on a numerical scale of 1 to 14, 7 being neutral. In general, stream pH is nearly neutral; slight acidity or alkalinity is indicative of concentrations of dissolved material in the water.

Dissolved Oxygen

The amount of dissolved oxygen in the water is important because aerobic decomposition is oxygen-dependent. If oxygen is not present in sufficient quantity to support aerobic decomposition, anaerobic decomposition takes place and often produces undesirable end products. In addition, maintenance of normal populations of fish and other aquatic organisms is dependent upon adequate quantities of dissolved oxygen.

Dissolved Solids

Normally, water hardness is a direct function of the amount of dissolved solids present in the water. While hardness is not often a health hazard, very hard water is not desirable for domestic use because of taste and residue problems.

Total Nitrate

Because nitrates are an end product of the normal decomposition of organic nitrogen compounds, measurement of nitrate levels in a given water source has been successfully used to determine at what time pollution of the water occurred. Knowledge of nitrate content is especially important in light of recent evidence that high nitrate levels pose a definite health hazard. This is particularly important in agricultural areas where nitrogen fertilizers are used extensively.

Total Coliform

Fecal coliform bacteria are a definite health hazard. Likely sources for coliform bacteria in rivers and streams are sewer treatment plant effluent, septic tank discharge, and grazing stock.

Examination of tables in Appendix F indicates that overall quality of surface water in the county is good. The water quality analyses reflect the geography of the stream basins. All principal streams within the county have a steep gradient which ensures good oxygenation and tends to prevent development of high water temperatures. In addition, the limited population and lack of related industry reduces the amount of potential pollutants.

Records from the White Salmon and Klickitat Rivers (Appendix F) show that the rivers have maintained consistently good quality through the period of analysis. Comparisons of analyses for the Klickitat River between 1910 and recent years demonstrate little variation in dissolved solids and total nitrates. A new sewage treatment facility at the town of Klickitat is reflected in the total coliform record of the station at Pitt. Prior to 1973 (the year in which the new facility came into service) the median value of total coliform was 556 mg/1, in contrast to 341 mg/1 after 1973.

Water Quality

Like the Klickitat River, the White Salmon River is relatively low in pollutants, with the possible exception of total coliform. The moderately high coliform count in the river is probably related to the presence of numerous homesites and their related septic systems along parts of the river and, to a lesser extent, to grazing along the river and some of its tributaries.

Classification of Washington Rivers and Streams

In 1970, regulations were initiated by the Water Pollution Control Commission of Washington setting water quality standards for intrastate rivers and streams and classifying the streams relative to these standards. The regulations established four classes of streams based on seven water quality criteria. The seven criteria are total coliform content, dissolved oxygen content, temperature, pH, turbidity, toxic, radioactive and deleterious material concentrations, and aesthetic value. The classes established are: AA-extraordinary, A-excellent, B-good, and C-fair.

In addition to the development of quality standards, the regulations assigned many of the rivers and streams in the state to one of the above classes, based on the stream's water quality. Both the Klickitat and White Salmon Rivers are classified A relative to the seven criteria listed above. Comparisons of Appendix F with the criteria established for each class reveals that for those criteria presented in the tables (total coliform, dissolved oxygen, temperature, and pH), the only criteria which necessitated classification of the two rivers as class A rather than AA was total coliform content. For both streams, total coliform median values exceeded the class AA limit of 50 and approached the class A limit of 240. This comparison suggests that both the White Salmon and Klickitat rivers are of relatively high quality and it is likely that the standards for these two rivers are representative for most of the perennial streams in Klickitat County.

Ground-Water Quality

Availability of information on ground-water quality within the study area is limited. Most of the data available are from the central part of the county and were collected by Luzier (1969) from the Goldendale-Centerville area. Some ground-water quality data are also available for the Camas Prairie area from work by Cline (1976).

As in surface-water quality studies, selected properties and constituents of ground water are tested to determine overall quality. In general, the water is tested for selected anions and cations dissolved in the water. Generally, the particular ions chosen are those which make up the bulk of the dissolved material in the water and thus are the principal determinants of water quality. A compilation of water analyses from wells and springs in Klickitat County is presented in Tables G-1 and G-2, Appendix G. As can be seen in the tables, the principal ions chosen for analyses are silica, chloride, calcium, iron, magnesium, sodium, potassium, bicarbonate, carbonate, fluoride, nitrate and orthophosphate. In addition to these ions, conductivity, pH and total hardness were determined, as these parameters often give a general assessment of water quality. Of the constituents tested, iron, calcium, magnesium, bicarbonate, carbonate, sulfate and chloride are perhaps the most important for ground waters of Klickitat County.

In 1962, the U. S. Public Health Service established general drinking water standards for the United States. Table 6 presents these standards to provide a comparison with the water quality analyses presented in Appendix G.

TABLE 6. Maximum allowable concentration of selected constituents for public water supplies.

Substance	Concentration mg/1
Arsenic (As)	0.01
Barium (Ba)	1.0
Boron (B)	1.0
Cadmium (Cd)	0.01
Carbon Chloroform Extract (CCE)	0.2
Chloride (Cl)	250.0
Chromium (hexavalent, Cr^{+6})	0.05
Copper (Cu)	1.0
Cyanide (CN)	0.01
Fluoride (F)	2.0
Iron (Fe)	0.3
Lead (Pb)	0.05
Mercury (Hg)	0.005
Manganese (Mn)	0.05
Nitrogen (n) (nitrate plus nitrite)	10.0
Selenium (Se)	0.01
Silver (Ag)	0.05
Sulfate (SO_4)	250.0
Total Dissolved Solids (TDS)	500.0
Zinc (Zn)	5.0

Many of these standards were incorporated into the Washington State Rules and Regulations regarding public water supplies and are thus the minimum standards for quality of public water supplies within the state.

Specific Properties and Constituents

Iron

The presence of levels of dissolved iron in water in excess of 0.3 mg/1 is generally considered undesirable because of taste, staining, and residue problems. Most wells and springs sampled within the county have iron levels well below the 0.3 mg/1 limit. In most cases, those ground-water sources with high iron levels were in the unconsolidated sediments of the Swale Creek valley and the Camas Prairie area where higher iron values are more likely to occur. Some wells penetrating basalt aquifers also exhibit high iron content, however. The recently drilled City of Goldendale well (4/16-16Q2) had one analysis of 0.26 mg/1 iron, which approaches the recommended limit. A second analysis of the well, however, gave a much lower iron value, which suggested the iron content may not be as high as originally indicated.

Although no analyses were available, visual inspection of water supply facilities in the White Salmon River drainage, near Husum, indicates the possibility of high iron concentrations in ground water. Several domestic residences have experienced severe iron staining and incrustation problems. Most of the wells in the area are drilled into younger volcanics in the river valley with aquifers often located in the sedimentary interbeds. The source of the iron is not known but may be derived from the younger volcanic flows. Because of the majority of potable water wells tap basalt aquifers, iron does not appear to be a serious problem in most areas of the county.

Calcium and Magnesium

Calcium and magnesium make up a substantial part of all dissolved cations in most of the ground waters sampled. It is principally calcium and magnesium which combine with soap to form the relatively insoluble precipitates commonly associated with hard water. Newcomb (1972) found that in the aquifers of the Columbia River Basalt Group, calcium and magnesium ranged from 20 to 100 mg/1. As can be seen from Appendix G, most of the values for ground-water sources within the county fall within this range.

Newcomb suggests that much of the calcium present in ground-water supplies is obtained from percolation through the soil and superficial weathering zone of the basalts. This would seem likely, as those wells which fail to penetrate the basalts have much the same calcium content as those which tap basalt aquifers. Newcomb also noted an increase in these cations in areas where there was substantial irrigation return flow. It is possible that in areas of heavy irrigation within the county some concentration of these cations in the ground-water supply may be noted.

Bicarbonate

Like the cations magnesium and calcium, bicarbonate is a principal anion in normal ground waters of the Columbia River Basalt Group. Newcomb (1972) lists bicarbonate values ranging from 50 to 300 mg/1 and most of the sources sampled within Klickitat County are well within that range. Within the county, most samples show bicarbonate values between 30 and 150 mg/1.

Hardness

A combination of several of the above constituents contributes to a water characteristic referred to as hardness. Hardness is generally calculated in mg/1 of $CaCO_3$ because it is normally the calcium and, to a lesser extent, the magnesium cations, and the carbonate and bicarbonate anions which are the significant determinants of hardness. Tables G-1 and G-2, Appendix G, present hardness values for wells and springs in Klickitat County.

The relatve hardness scale commonly used is presented by Brown and others (1970) and is as follows: 0-60 mg/1, soft; 61-120 mg/1, moderately hard; 121-180 mg/1, hard; and greater than 180 mg/1, very hard. Based on this scale, most of the county's ground-water sources are in the moderately hard to hard range although a substantial number (12 of 86) of the wells sampled showed very hard conditions. The reason for these hard water wells is not readily apparent but may relate to irrigation of sedimentary deposits in the Swale Creek area. This seems to be substantiated by Vandenburg and Santos

(1965), who documented a relationship between well depth and hardness for wells in their Columbia Plateau Province. They found that a decrease in hardness occurred with depth and attributed it to the fact that small amounts of calcium and magnesium surface sediments must be concentrated in irrigation return waters.

Unique Occurrences

Within Klickitat County there are several occurrences of ground water of very anomalous quality. The best known of these occurrences is along the Klickitat River between the towns of Klickitat and Wahkaicus. Here, an occurrence of soda springs led to the drilling of many wells, several of which flow. The water from both the springs and wells was found to be charged with carbon dioxide and an extraction plant was constructed to extract the CO_2 for dry ice. Analyses from two of the wells in the immediate area (4/13-24H1 and 4/14-19C1) are presented in Table G-1, Appendix G. Examination of these analyses reveals the waters to have a very high dissolved solids content. Silica, calcium, magnesium, iron, sodium and potassium are much higher than in most other wells in the county. Newcomb (1972) suggests that these levels are much higher than most ground-water sources of the Columbia Plateau.

Springs with water of similar unique chemical composition have been noted by Cline (1976); the analyses are presented in Table G-2, Appendix G. The presence of these highly unusual ground-water sources is not fully understood. The proximity of these waters to the younger volcanics has led most researchers to propose a relatively warm, deep-seated source with migration of the surface being facilitated by near-vertical fault zones.

Water Quality

Summary

Water quality information indicates that, in general, Klickitat County enjoys ground water of good quality. Analyses of water from basalt wells indicate that although the water is moderately hard, it contains relatively minor amounts of other dissolved solids and lacks traces of toxic chemicals. Waters obtained from wells and springs in the sediments are generally of poorer quality than those from underlying basalt aquifers but in most cases are still quite usable. The sedimentary aquifers have slightly higher calcium, magnesium and bicarbonate contents which result in slightly higher hardness; some contain high concentrations of iron. Ground-water sources from the younger volcanics are of varying quality with some wells in the White Salmon River Valley also having high iron concentrations.

WATER USE

Introduction

Much of the Klickitat County is semiarid with little appreciable precipitation occurring during the summer crop-growing months. As a result, surface- and ground-water resources have been important since the area was first settled. In the early days, the perennial streams in the central and western parts of the county were immediately recognized as sources of irrigation and stockwater and many were heavily appropriated. Later, availability of ground-water supplies led to increased development of well irrigation in the central and eastern parts of the county. Currently, much of the county's surface-water resources are fully appropriated and the demand for ground water is continuing to increase.

Water-Right Law

Although the water resources of the State of Washington are a public trust, the right of private individuals to use these resources was established in Article XXI of the State Constitution. The procedure for securing such a right was established in Chapter CXLII, Session Laws of 1891. Most of the early water appropriations involved surface waters, but a growing population and limited surface-water resources soon resulted in problems. As a result of these problems a Surface Water Code was established in Chapter 117, Laws of 1917. Unlike anything prior to this time, the laws established an office of Hydraulic Engineer (now incorporated in the Department of Ecology) and established a formal water-right application procedure which included review by the Hydraulic Engineer and an opportunity for formal protest by all concerned parties. The Surface Water Code, as established in 1917, is essentially the same as that in operation today.

Concern over rights to ground water within the state did not become manifest until the 1940's. In response to this concern, the legislature passed the Washington State Ground Water Code to establish procedures for securing a right to ground-water withdrawal. The procedure established is much the same as that set forth in the Surface Water Code. Applicants must apply for a permit and, if granted, they may begin improvements and subsequently make withdrawals. Once the well or works have been constructed and the water is put to beneficial use, certification is effected and the actual water right is secured. Ground-water withdrawals of less than 5,000 gallons per day are exempt from the above procedure.

In 1967, the Washington State Legislature passed the Water Rights Claim Registration Act in an attempt to obtain a more complete inventory of water use within the state. The act specified a five-year period from 1969 to 1974 during wich claims were to be filed. Everyone who claimed a right to the use of surface or ground waters within the state was required to file a water right claim. Those holding water rights issued by the state were exempted from this program.

Water Rights in Klickitat County

Examination of water-right records of the Department of Ecology reveals a total of 1015 water-right claims in Klickitat County. Of these, 401 are for ground water, 594 are for surface water, and 20 are for reservoir water, principally from the Columbia River. For management purposes, the Department of Ecology considers springs as surface-water sources, and they are so included in this report. The 401 ground-water claims are for a total of 157, 913.5 gpm and the 594 surface claims for a total of 568.55 cfs. Principal use of the water resources of the county is irrigation.

The claims are in all stages, from application through certification, and no attempt has been made to distinguish them further. Appendix H contains a list of all surface-water and ground-water claims as of June 30, 1976. Those that have been certificated are so indicated. Tables 7 through 12 and 16 through 24 present a breakdown of periodic claim totals by individual drainage basin and a distribution of the claim with respect to both time and geophysical area. The tables present both the instantaneous appropriation in cfs (gpm for ground water) and annual appropriation in acre-feet. In many instances, the instantaneous amount is specified but the annual appropriation is not. Lack of both an instantaneous and annual figure for every claim accounts for the differences in amount apparent between the two columns in each of the tables. The tables do provide a good indication of water-resource development within the county over the last 25 years.

Analysis of Individual Drainage Basins

White Salmon River Basin

Table 7 reveals that surface-water fillings within the White Salmon River basin have changed gradually since 1950. Between 1950 and 1955 the total number of claims almost doubled and then changed little until after 1970. The change of 28.34 cfs between 1970 and 1976 is quite likely because of the Water Right Claim Registration Act and the effort from 1969 and 1974 to encourage filing of water-right claims. The total amount surface water claimed (116.12 cfs) is substantially less than the low flow of the White

Salmon River at Underwood (see Table 4), which suggests that some water may still be available for appropriation. However, existing rights, hydroelectric power requirements, and fish and wildlife requirements must all be taken into consideration.

Ground-water claims within the basin, though insignificant in comparison to surface-water claims, have increased substantially in the last ten years. Part of this increase is undoubtedly in response to the registration act, but may be partly attributed to recent interest in irrigating higher plateau areas where adequate surface-water supplies do not exist.

Major-Creek Basin

The small size and steep topography of the Major Creek basin has understandably limited the amount of surface-water claims (Table 8). A total of 1.61 cfs has been requested, most of which is for domestic and stockwater uses and is obtained from small springs within the basin.

Ground-water claims in the area are also small but approach in total quantity that of the much larger White Salmon River basin. Most of the ground-water fillings were made between 1970 and 1975 and are likely in response to the registration act.

Klickitat River Basin

The Klickitat River basin is the largest drainage basin in the county and includes the subsidiary drainage basins of the Little Klickitat River and Swale Creek. The amount of surface water claimed within the Klickitat River basin totaled 437.25 cfs as of 1976 (Tables 10, 11, and 12). Of this total, 87% or 378.34 cfs is claimed within the main Klickitat River basin exclusive of the Little Klickitat and Swale Creek basins. Most of these surface-water claims within the Klickitat River basin are in the Camas Prairie area and

and in the western part of the basin. Comparison of total number of cfs claimed in 1950 and in 1976 (Table 10) reveals little increase in appropriation over the 26 year period. This is not particularly surprising as many of the claims date back to the late 1800's and are some of the earliest surface-water claims in the county. Most claims are for domestic and stock use and for irrigation of Camas Prairie.

As in the western part of the Klickitat River basin, there has been relatively little change in surface-water claims in the Little Klickitat River basin since 1950. The surface-water resources available in the Little Klickitat basin are substantially less than in other parts of the Klickitat basin and most of the resources were appropriated in the late 1800's.

Ground-water claims within the Klickitat River basin are almost exclusively restricted to the Little Klickitat and Swale Creek basins. Only 2044 gpm or 3% of the total amount claimed for the entire Klickitat River basin are from locations outside the Little Klickitat and Swale Creek basins. Tables 11 and 12 reveal a substantial increase in listings between 1970 and 1975 for both basins. A part of the increase between 1970 and 1975 is probably attributable to the registration act; however, analysis of irrigation power requirements presented in Table 13 indicates a steady increase in both customers and total kilowatt-hours (KWH) per year. This suggests that a substantial part of the increase does indeed indicate an increase in ground-water withdrawal.

An attempt was made to determine what effect, if any, the increased withdrawal in the Little Klickitat and Swale Creek basins had upon the streams in the area, particularly the Little Klickitat River. The analysis involved comparisons of stream discharge records between the gaging station at Goldendale, which is located above most of the ground-water withdrawals in the basin, and the station at Wahkaicus where the Little Klickitat River enters the Klickitat River. A simple ratio was calculated between monthly mean discharges at each station for the six-month period of May through October and for the three-month low-flow period of July, August and September. The analysis was complicated by several factors including: 1) unregulated discharge of the Goldendale sewer plant into the Little Klickitat River; 2) unknown withdrawals directly from the stream; 3) lack of adequate gaging station records.

Tables 14 and 15 contain the results of the analysis. Little consistent change in the ratio is apparent through the period of increased pumping, which would suggest the increased withdrawal of ground water has little effect upon the flow of the Little Klickitat River. Considering the general nature of the method and the numerous variables involved, more detailed modeling efforts using improved withdrawal figures are needed.

Alder Creek and Dead Canyon Basins

The Alder Creek and Dead Canyon-Glade Creek basins occupy a substantial part of the eastern third of the county. There is virtually no surface water in the area, and accordingly there are no claims for surface-water rights. Substantial deep-well irrigation is being developed, and Tables 17 and 18 reflect this. Prior to 1950, no ground-water rights were recorded in these areas, while the combined areas now account for 54,290 gpm or 34% of the total ground-water claims in the county. While a part of this total is probably related to the registration act, the change in amount in the Alder Creek basin (Table 17) between 1975 and 1976 reflects the continuing interest in deep-well irrigation potential of these areas.

Other Basins

Tables 19 through 24 contain water-right listings for several of the smaller basins in the eastern half of Klickitat County. Included in these tables are Rock Creek, Wood Gulch, Chapman Creek, Old Lady Canyon, and Pine Creek basins. These basins lie in the drier eastern part of the county and include large areas not suited for irrigation. The lack of surface water, particularly during the summer months, limits most of the surface-water right listings to springs used for domestic or stockwater purposes. Some of the basins have no surface-water listings whatsoever.

Most basins have a few ground-water listings; the total of all five basins amounts to 15,834 gpm. Many of these rights are for domestic and stock uses.

TABLE 7. Summation of surface- and ground-water appropriation, White Salmon River basin, Klickitat County, Washington.

Year	Surface Water		Ground Water	
	cfs	acre-feet	gpm	acre-feet
1950	43.60	0.12	67.0	38.0
1955	74.80	187.13	67.0	38.0
1960	79.20	1411.63	117.0	66.0
1965	80.05	1594.63	217.0	91.6
1970	87.78	3022.92	894.0	322.1
1975	116.12	5824.72	1368.0	473.9
1976	116.12	5824.72	1393.0	473.9

TABLE 8. Summation of surface- and ground-water appropriation, Major Creek basin, Klickitat County, Washington.

Year	Surface Water		Ground Water	
	cfs	acre-feet	gpm	acre-feet
1950	--	--	--	--
1955	0.01	--	--	--
1960	0.24	--	--	--
1965	0.80	128.5	--	--
1970	0.90	128.5	47.0	25.0
1975	1.61	156.5	1283.5	53.0
1976	1.61	156.5	1283.5	53.0

TABLE 9. Summation of surface- and ground-water appropriation, Water Resource Inventory Area 29 exclusive of the White Salmon River basin, Klickitat County, Washington.

Year	Surface Water		Ground Water	
	cfs	acre-feet	gpm	acre-feet
1950	0.25	--	--	--
1955	0.25	--	500.0	800.0
1960	0.85	120.0	500.0	800.0
1965	2.90	1019.0	560.0	831.2
1970	2.96	1031.0	1870.0	1705.2
1975	4.69	1356.3	2696.5	2289.7
1976	5.19	1356.3	2696.5	2289.7

TABLE 10. Summation of surface- and ground-water appropriation, Klickitat River basin exclusive of Little Klickitat River and Swale Creek basins, Klickitat County, Washington.

Year	Surface Water		Ground Water	
	cfs	acre-feet	gpm	acre-feet
1950	341.20	1.0	--	--
1955	353.24	2.75	390.0	287.0
1960	353.55	45.75	410.0	296.6
1965	355.75	488.75	430.0	298.6
1970	360.22	1326.35	589.0	430.6
1975	378.34	2817.69	1009.0	532.6
1976	378.34	2817.69	2044.0	532.6

TABLE 11. Summation of surface- and ground-water appropriation, Little Klickitat River basin, Klickitat County, Washington.

Year	Surface Water		Ground Water	
	cfs	acre-feet	gpm	acre-feet
1950	38.23	1987.33	413.0	100.94
1955	38.80	2116.37	831.0	281.34
1960	39.92	2156.37	1374.0	532.54
1965	43.46	3020.47	3053.0	1596.68
1970	45.75	3178.67	26,838.0	12,243.1
1975	54.52	3465.47	47,304.0	21,486.1
1976	58.54	3465.47	47,464.0	21,486.1

TABLE 12. Summation of surface- and ground-water appropriation, Swale Creek basin, Klickitat County, Washington.

Year	Surface Water		Ground Water	
	cfs	acre-feet	gpm	acre-feet
1950	--	--	125.0	40.0
1955	--	--	125.0	40.0
1960	--	--	200.0	100.0
1965	--	--	465.0	296.0
1970	--	--	10,905.0	6124.1
1975	0.37	56.4	19,533.5	10,202.0
1976	0.37	56.4	19,533.5	10,202.2

TABLE 13. Electrical power usage for irrigation customers, Goldendale substation, Klickitat County, Washington.

Year	Number of Customers	KWH/yr/customer	Total KWH/yr
1960	--	--	1,925,896
1961	--	--	2,027,629
1962	--	--	2,474,585
1963	--	--	2,667,462
1964	70	40,305	2,821,350
1965	70	47,254	3,307,780
1966	80	49,176	3,934,080
1967	92	36,401	3,348,982
1968	107	50,184	5,369,688
1969	139	45,128	6,272,792
1970	154	48,749	7,507,346
1971	158	52,119	8,234,802
1972	166	48,131	7,989,746
1973	172	58,420	10,048,240
1974	186	57,385	10,673,610
1975	195	55,377	10,798,515
1976	204	61,933	12,634,322

TABLE 14. Comparison of monthly mean discharge (July-September) between stream gaging stations near Goldendale and Wahkaicus on the Little Klickitat River, Klickitat County, Washington.

Date		Monthly Mean Discharge (cfs)			
Year	Month	Goldendale (A)	Wahkaicus (B)	Ratio A/B	Average Ratio
1947	July	2.91	24.3	0.120	
	Aug.	1.09	19.9	0.055	
	Sept.	2.01	23.3	0.086	0.087
1948	July	11.2	49.3	0.227	
	Aug.	4.32	33.1	0.131	
	Sept.	3.18	29.4	0.108	0.155
1949	July	9.19	45.0	0.204	
	Aug.	3.38	35.0	0.097	
	Sept.	3.14	36.0	0.087	0.129
1950	July	18.9	66.0	0.286	
	Aug.	5.3	37.0	0.143	
	Sept.	3.7	31.0	0.119	0.183
1951	July	12.8	59.3	0.216	
	Aug.	4.35	42.3	0.103	
	Sept.	4.17	42.4	0.098	0.139
1958	July	6.65	36.1	0.184	
	Aug.	1.99	24.9	0.080	
	Sept.	2.65	31.6	0.084	0.116
1959	Aug.	1.30	20.8	0.065	
	Sept.	2.84	29.3	0.097	0.108
1960	July	4.83	24.6	0.196	
	Aug.	1.60	19.1	0.084	
	Sept.	1.29	24.2	0.053	0.111
1961	July	8.57	41.3	0.208	
	Aug.	3.13	29.7	0.105	
	Sept.	2.70	28.7	0.112	0.142
1963	July	5.17	35.3	0.147	
	Aug.	1.58	22.9	0.067	
	Sept.	1.21	23.9	0.051	0.087
1964	July	7.50	30.0	0.250	
	Aug.	2.71	21.0	0.129	
	Sept.	2.07	22.1	0.094	0.158

TABLE 14 (Cont'd)

Date		Monthly Mean Discharge (cfs)			
Year	Month	Goldendale (A)	Wahkaicus (B)	Ratio A/B	Average Ratio
1965	July	4.95	30.9	0.160	
	Aug.	2.67	25.0	0.107	
	Sept.	2.55	26.9	0.095	0.121
1966	July	11.9	39.3	0.303	
	Aug.	2.64	19.7	0.134	
	Sept.	2.36	24.2	0.098	0.178
1967	July	3.27	20.3	0.161	
	Aug.	0.63	12.5	0.050	
	Sept.	0.77	17.4	0.044	0.085
1968	July	1.59	15.8	0.101	
	Aug.	2.19	18.5	0.118	
	Sept.	2.88	25.6	0.113	0.111
1969	July	5.76	30.7	0.188	
	Aug.	1.71	20.6	0.083	
	Sept.	2.65	26.7	0.99	0.123
1970	July	4.44	25.9	0.171	
	Aug.	1.11	16.7	0.067	
	Sept.	1.14	18.2	0.063	0.100

TABLE 15. Comparison of monthly mean discharge (May-October) between stream gaging stations near Goldendale and Wahkaicus on the Little Klickitat River, Klickitat County, Washington.

Date		Monthly Mean Discharge (cfs)			
Year	Month	Goldendale (A)	Wahkaicus (B)	Ratio A/B	Average Ratio
1947	May	34.1	97.3	0.350	
	June	13.6	55.4	0.246	
	July	2.91	24.3	0.120	
	Aug.	1.09	19.9	0.055	
	Sept.	2.01	23.3	0.086	
	Oct.	19.1	54.6	0.350	0.201
1948	May	102.0	242.0	0.422	
	June	51.3	146.0	0.351	
	July	11.2	49.3	0.227	
	Aug.	4.32	33.1	0.131	
	Sept.	3.18	29.4	0.108	
	Oct.	5.08	35.0	0.145	0.231
1949	May	118.0	320.0	0.369	
	June	39.0	120.0	0.325	
	July	9.19	45.0	0.204	
	Aug.	3.38	35.0	0.097	
	Sept.	3.14	36.0	0.087	
	Oct.	4.89	32.0	0.153	
1950	May	88.4	280.0	0.316	
	June	67.0	170.0	0.394	
	July	8.9	66.0	0.286	
	Aug.	5.3	37.0	0.143	
	Sept.	3.7	31.0	0.119	
	Oct.	14.3	54.3	0.263	0.254
1951	May	107.0	297.0	0.360	
	June	44.9	125.0	0.359	
	July	12.8	59.3	0.216	
	Aug.	4.35	42.3	0.103	
	Sept.	4.17	42.4	0.098	0.227
	Oct.	--	--	--	
1958	May	83.6	194.0	0.431	
	June	24.5	77.6	0.316	
	July	6.65	36.1	0.184	
	Aug.	1.99	24.9	0.080	
	Sept.	2.65	31.6	0.084	
	Oct.	3.89	35.6	0.109	0.201

TABLE 15 (Cont'd)

Date		Monthly Mean Discharge (cfs)			
Year	Month	Goldendale (A)	Wahkaicus (B)	Ratio A/B	Average Ratio
1959	May	37.5	96.6	0.388	
	June	18.4	51.2	0.359	
	July	4.16	25.8	0.161	
	Aug.	1.36	20.8	0.065	
	Sept.	2.84	29.3	0.097	
	Oct.	4.4	38.0	0.116	0.198
1960	May	62.3	161.0	0.387	
	June	28.6	74.4	0.384	
	July	4.83	24.6	0.196	
	Aug.	1.6	19.1	0.084	
	Sept.	1.29	24.2	0.053	
	Oct.	2.75	30.8	0.089	0.199
1961	May	69.7	179.0	0.389	
	June	40.0	98.7	0.427	
	July	8.57	41.3	0.208	
	Aug.	3.13	29.7	0.105	
	Sept.	2.7	28.7	0.094	
	Oct.	5.48	37.7	0.145	0.228
1962	May	60.4	152.0	0.397	
	June	30.4	72.4	0.420	
	July	7.16	33.6	0.213	
	Aug.	3.11	27.8	0.112	
	Sept.	2.4	26.8	0.090	
	Oct.	8.83	45.7	0.193	0.238
1963	May	56.7	152.0	0.373	
	June	17.7	62.3	0.284	
	July	5.17	35.3	0.147	
	Aug.	1.58	22.9	0.069	
	Sept.	1.21	23.9	0.051	0.171
	Oct.	2.92	30.4	0.096	
1964	May	50.8	110.0	0.462	
	June	36.9	82.8	0.448	
	July	7.5	30.0	0.250	
	Aug.	2.71	21.0	0.129	
	Sept.	2.07	22.1	0.094	
	Oct.	3.6	32.5	0.111	0.250

TABLE 15 (Cont'd)

Date		Monthly Mean Discharge (cfs)			
Year	Month	Goldendale (A)	Wahkaicus (B)	Ratio A/B	Average Ratio
1965	May	50.1	130.0	0.385	
	June	23.4	70.0	0.334	
	July	4.95	30.9	0.160	
	Aug.	2.67	25.0	0.107	
	Sept.	2.55	26.9	0.095	
	Oct.	4.3	32.2	0.134	0.203
1966	May	64.6	151.0	0.428	
	June	26.8	62.4	0.430	
	July	11.9	39.3	0.303	
	Aug.	2.64	19.7	0.134	
	Sept.	2.36	34.2	0.098	
	Oct.	4.02	32.2	0.125	0.253
1967	May	51.7	109.0	0.474	
	June	24.4	59.7	0.409	
	July	3.27	20.3	0.161	
	Aug.	0.63	12.5	0.050	
	Sept.	0.77	17.4	0.044	
	Oct.	6.15	32.3	0.190	0.222
1968	May	16.0	52.2	0.307	
	June	6.27	33.6	0.187	
	July	1.59	15.8	0.101	
	Aug.	2.19	18.5	0.118	
	Sept.	2.88	25.6	0.113	
	Oct.	6.17	33.1	0.186	0.169
1969	May	89.6	212.0	0.423	
	June	30.2	94.3	0.320	
	July	5.76	30.7	0.188	
	Aug.	1.71	20.6	0.083	
	Sept.	2.65	26.7	0.099	
	Oct.	5.27	37.8	0.139	0.209
1970	May	53.9	115.0	0.469	
	June	28.7	60.4	0.475	
	July	4.44	25.9	0.171	
	Aug.	1.11	16.7	0.067	
	Sept.	1.14	18.2	0.063	0.249
	Oct.	--	--	--	

TABLE 16. Summation of surface- and ground-water appropriation, Water Resource Inventory Area 30 exclusive of Klickitat River basin, Klickitat County, Washington.

Year	Surface Water cfs	Surface Water acre-feet	Ground Water gpm	Ground Water acre-feet
1950	4.91	--	1800	637.0
1955	5.45	--	4030	221.4
1960	5.49	4.0	4840	3517.4
1965	4.70	44.0	5182	3651.5
1970	6.42	265.5	7362	5105.0
1975	7.07	288.5	9544	5834.1
1976	7.07	288.5	9544	5834.1

TABLE 17. Summation of surface- and ground-water appropriation, Alder Creek basin, Klickitat County, Washington.

Year	Surface Water cfs	Surface Water acre-feet	Ground Water gpm	Ground Water acre-feet
1950	--	--	--	--
1955	--	--	--	--
1960	--	--	1600	640.0
1965	--	--	1600	640.0
1970	--	--	1600	640.0
1975	--	--	8800	2515.0
1976	--	--	13,800	2515.0

TABLE 18. Summation of surface- and ground-water appropriation, Dead Canyon and Glade Creek basins, Klickitat County, Washington.

Year	Surface Water		Ground Water	
	cfs	acre-feet	gpm	acre-feet
1950	--	--	--	--
1955	--	--	200.0	160.0
1960	--	--	890.0	680.0
1965	--	--	890.0	680.0
1970	--	--	7490.0	7557.0
1975	--	--	40,490.0	12,251.0
1976	--	--	40,490.0	12,251.0

TABLE 19. Summation of surface- and ground-water appropriation, Rock Creek basin, Klickitat County, Washington.

Year	Surface Water		Ground Water	
	cfs	acre-feet	gpm	acre-feet
1950	--	--	--	--
1955	--	--	--	--
1960	0.4	--	50.0	20.0
1965	0.6	69.0	50.0	20.0
1970	0.63	73.1	2657.0	860.0
1975	0.69	100.1	7813.0	3516.9
1976	0.69	100.1	7813.0	3516.9

TABLE 20. Summation of surface- and ground-water appropriation, Wood Gulch basin, Klickitat County, Washington.

Year	Surface Water cfs	Surface Water acre-feet	Ground Water gpm	Ground Water acre-feet
1950	--	--	--	--
1955	--	--	--	--
1960	--	--	--	--
1965	--	--	--	--
1970	--	--	3150.0	2175.0
1975	0.015	1.0	3150.0	2175.0
1976	0.015	1.0	3150.0	2175.0

TABLE 21. Summation of surface- and ground-water appropriation, Chapman Creek basin, Klickitat County, Washington.

Year	Surface Water cfs	Surface Water acre-feet	Ground Water gpm	Ground Water acre-feet
1950	--	--	--	--
1955	0.26	50.0	2650.0	1010.0
1960	0.26	50.0	2650.0	1010.0
1965	0.26	50.0	2650.0	1010.0
1970	0.26	50.0	2650.0	1010.0
1975	0.26	50.0	2650.0	1010.0
1976	0.26	50.0	2650.0	1010.0

TABLE 22. Summation of surface- and ground-water appropriation, Old Lady Canyon basin, Klickitat County, Washington.

Year	Surface Water cfs	Surface Water acre-feet	Ground Water gpm	Ground Water acre-feet
1950	--	--	--	--
1955	--	--	--	--
1960	--	--	--	--
1965	--	--	--	--
1970	--	--	--	--
1975	--	--	12.0	2.0
1976	--	--	12.0	2.0

TABLE 23. Summation of surface- and ground-water appropriation, Pine Creek basin, Klickitat County, Washington.

Year	Surface Water cfs	Surface Water acre-feet	Ground Water gpm	Ground Water acre-feet
1950	--	--	--	--
1955	--	--	--	--
1960	0.24	48.0	--	--
1965	0.24	48.0	--	--
1970	0.25	49.0	9.0	2.0
1975	0.25	49.0	9.0	2.0
1976	0.25	49.0	9.0	2.0

TABLE 24. Summation of surface- and ground-water appropriation, Water Resource Inventory Area 31 exclusive of Rock Creek, Wood Gulch, Chapman Creek, Old Lady Canyon, Pine Creek, Alder Creek, Dead Canyon, and Glade Creek basins, Klickitat County, Washington.

	Surface Water		Ground Water	
Year	cfs	acre-feet	gpm	acre-feet
1950	0.01	--	200.0	111.0
1955	0.01	--	200.0	111.0
1960	0.09	22.0	200.0	111.0
1965	0.09	22.0	681.0	414.8
1970	0.09	22.0	2681.0	3614.8
1975	0.09	22.0	3831.0	3893.8
1976	0.09	22.0	3831.0	3893.8

SUMMARY

Klickitat County and the upper Klickitat River basin occupy an area in excess of 2200 square miles in south-central Washington. The area is a geographical transition zone between the Cascade Mountains on the west and the Columbia plateau to the east, and its transitional nature is evident in the area's climate, geology, and in the nature and occurrence of its water resources.

The climate of Klickitat County changes from humid and subhumid in the west to semiarid and arid in the east. Eastward migrating storms associated with low pressure systems dominate the county's weather in the winter months. During these months the weather is cool and wet. In the summer, high pressure dominates bringing warm and dry conditions to the area.

Most precipitation occurs as rain or snow during the winter months with annual rainfall decreasing markedly from west to east. Annual precipitation varies from 70 inches in the west to less than 10 in the east. Abundant precipitation also occurs in areas of high elevation with annual totals exceeding 100 inches on Mt. Adams in the northwest part of the study area. Precipitation is low in the Columbia River gorge because of its low elevation and the expansion of air flow east of the Cascade water gap. Long-term records reveal a cyclical distribution of precipitation.

Average monthly temperatures range from 65-70°F in July to 30°F in January. Temperature is also controlled by elevation with warmer temperatures occurring at lower elevations. Long-term temperature averages indicate temperatures lower than the mean during the 1920's and 1930's. Temperatures have remained at or near the mean for the last 15 years.

Water budget calculations done for several locations in the county reflect the areal variation in precipitation and temperature. Stations in the

western part of the county have a large water surplus in early spring and small water deficits in the summer months. Conversely, locations in the east have low precipitation and high evapotranspiration resulting in a high water deficit and no water surplus.

Within the study area, four major geologic units are recognized. The oldest of these, the older volcanic and volcaniclastic rocks, consists of tuffs and tuff breccias with some interbedded basaltic and andesitic lavas. Exposure of these rocks is limited to the northwest corner of the county.

Overlying the older volcanics is a sequence of basalts of the Columbia River Group. These basalts are the most extensive unit in the study area and appear to thicken to the east. Units of the group exposed are those of the Wanapum and Grande Ronde basalts in the west and the Saddle Mountains Basalt to the east.

In protected areas, the Columbia River Basalt is overlain by a sequence of Tertiary-Quaternary sediments. In the central part of the county the sediments are mainly a quartzite conglomerate in a tuffaceous matrix. To the west the sediments contain less quartzite and more basalt and andesite.

The youngest geologic unit recognized is the younger volcanics present in the north and west part of the study area. This unit includes the Simcoe Mountain volcanics north of Goldendale and the younger basaltic and andesitic lavas associated with Mt. Adams and other eruptive centers to the west.

Distribution of surface-water resources is in direct relation to available precipitation within the study area. Very intermittent streams characterized by rapid runoff, wide discharge variation, and no sustained minimum flow are present in the arid eastern part of the study area. Conversely, streams in the west exhibit less discharge variation and substantial minimum flows sustained by ground-water discharge and snowmelt during the summer months. Streams in the county's central part represent a transition between the two extremes with high runoffs and low but sustained minimum flows. Peak flows for all streams occur in late winter months and minimum flows occur in late summer and early fall.

Ground-water resources appear more widely available throughout the study area than surface water. In the western third of the county, numerous springs exist, most issuing from permeable zones in the Columbia River Basalt and younger volcanics. In the rest of the county, wells are the primary ground-water source, and most obtain adequate supplies from permeable interflow zones in the Columbia River Basalt Group. In the Goldendale-Centerville area, irrigation wells capable of 1000-1500 gpm have been developed and well irrigation is extensive. In the Dead Canyon and Glade Creek areas, near the county's eastern edge, high production irrigation wells have been obtained, some of which flow in excess of 2000 gpm. Analysis of well hydrographs indicate that in most areas annual recharge appears sufficient to keep up with present demand. In the eastern part of the county, however, some evidence exists to indicate that recharge is insufficient, particularly in the Bickleton area.

Water quality within the study area appears to be good. Analysis of major streams within the county indicates most to have water of excellent quality. A few of the sample locations indicate coliform content to be higher than desirable, probably as a result of septic tank effluent and livestock grazing in close proximity to the stream.

Ground-water quality also appears to be generally good. A few wells in the younger volcanics appear to have a high iron content and wells located in sediments show some iron and hardness problems. Isolated instances of soda springs and wells are also found within the study area. These ground-water sources have a high chemical and mineral content and are undesirable for most domestic purposes. In general, however, water quality is good and, with adequate protection, should remain so.

A review of water-right claims for the study area reveals a total of 1015 claims. Of these, 594 claims are for a total of 568.55 cfs on surface water and 401 are for a 157,913.5 gpm of ground water. Many of the surface-water claims are long-standing and date back to the late 1800's when the area was first settled. Many of the ground-water claims have resulted from relatively recent interest in deep-well irrigation. An increase in the number of claims is noted in the last 10 years which is attributable in part to increased demand and to the Water Right Claim Regulation Act.

Most surface-water supplies are near fully appropriated and ground-water supplies will undoubtedly have to meet most of the future demand. Currently, ground-water supplies in much of the county appear adequate to meet this demand; however, care must be exercised in its development. Some areas, particularly in the eastern third of the county, appear to be marginal and extensive ground-water withdrawal could do serious harm. Thus, before substantial ground-water withdrawal is permitted in these areas its effects must be carefully assessed.

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